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Association of Tropical Biology & Conservation:
Asia-Pacific Chapter

Are Cambodia's coral reefs healthy?

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Cover photo: An owl moth *Brahmaea hearseyi* (family Brahmaeidae) encountered in Phnom Samkos Wildlife Sanctuary, Cardamom Mountains, Southwest Cambodia (© Jenny Daltry, FFI). This large insect is widely distributed across the Asia-Pacific region, from the Himalayas and western China to Java and the Philippines. Its markings resemble the head of a reticulated python, and probably serve to ward off birds and other predators.

Guest Editorial—The Association for Tropical Biology and Conservation (ATBC) Asia–Pacific Chapter meets in Cambodia

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In May 1999 I had the privilege of being one of the first scientists in many years to be given a short window of access to the remote lowland forests and pristine mid-elevation grasslands of northeastern Cambodia. My mission was to conduct a camera-trapping survey for tigers. Unfortunately that survey effort in Virachey National Park yielded no tigers. However, the “bycatch” records from our cameras did reveal the presence of other significant wildlife and, serendipitously, in the course of travelling to the survey location, our team was able to document the presence of an even more interesting mammal than the original target: a possibly new species of douc langur! That particular find was later described in this journal’s first issue (Rawson & Roos, 2008).

In the decade following our primate discovery, and as access to previously restricted areas increased, scientists and conservation organisations in Cambodia focused resources on biodiversity inventories and monitoring. I was lucky enough to be involved in the first formal wildlife surveys in Bokor National Park and in the protected forests of Mondulhiri and Preah Vihear that revealed new species records and range extensions for Cambodia. During this period, the numbers of amphibians, reptiles and fish known to occur in Cambodia each more than doubled, mammals increased by 62%, and birds by 40% (Daltry, 2011). The number of new species and new records for the country has continued to increase (Duckworth *et al.*, 2001; Daltry, 2013; Mahood *et al.*, 2013; Geissler *et al.*, 2015).

Knowledge of habitat affinities, species ecology and threats has burgeoned in the last 15 years as conservation resources and efforts have targeted sites and landscapes ranging from the flooded forests of the Tonle Sap to the Mekong grasslands, evergreen forests of the Cardamom Mountains, and the extensive deciduous dipterocarp forest of the Northern and Eastern Plains. The first long-term studies in

many years have been carried out for bats (Phauk *et al.*, 2013), primates (Starr *et al.*, 2011), birds (Keo, 2008; Goes, 2013), turtles (Platt *et al.*, 2008), large mammals (Gray & Phan, 2011; O’Kelly *et al.*, 2012) and aquatic fauna (Campbell *et al.*, 2006).

At the same time, capacity for biodiversity research and conservation has progressed in leaps and bounds in Cambodia. Now in its tenth year, the Centre for Biodiversity Conservation (CBC) at the Royal University of Phnom Penh has emerged as an important repository for specimens and a national centre of excellence and capacity building for taxonomic research and conservation. The CBC offers a MSc in Biodiversity Conservation course and produces a dozen Masters theses annually (Souter, 2013). Some graduates of this programme are now instructing their own degree courses and continue to be involved in local biodiversity research. Others have gone on to further study abroad.

Conservation NGOs have sponsored government officials to take higher degree courses in foreign universities, with some of these individuals having returned to take up leading roles on protected area and biodiversity conservation initiatives, in government agencies and NGOs.

National laws and policies have developed around the premises that wildlife, fisheries and forest resources are important to conserve and should be protected in their own right and for the benefit of local people living in and around them. Cambodia has established 23 protected areas, 10 protected forests and 58 fish sanctuaries, and has made measurable progress towards a quarter of the Aichi Biodiversity Targets (Government of Cambodia, 2014).

However, national budget allocations for conserving biodiversity and improving the livelihoods of local communities remain so low that few sites set aside for biodiversity conservation are effec-

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tively managed and large areas inside them are subject to forest clearance and unsustainable harvest of wildlife, timber and other forest resources. In the marine realm, coral reefs are being exploited and fish and other marine species have become increasingly vulnerable to over-harvesting and other anthropogenic threats (see Thorne *et al.*, 2015, in this issue). There is clearly a long way to go to achieve a balance between Cambodia's development goals and biodiversity conservation.

On the positive side, Cambodia is now a base for major international environmental initiatives hosted by the government (e.g. REDD+, climate change), most of the larger international conservation NGOs, and a plethora of local environmental NGOs and think-tanks, and this country has become a destination for regional and international biodiversity meetings.

It is with this background that I am delighted to announce the ninth meeting of the Association for Tropical Biology and Conservation (ATBC) Asia-Pacific Chapter. The ATBC is the world's largest group of scientists dedicated to the study and preservation of tropical diversity. The ATBC Asia-Pacific Chapter has chosen to meet in Phnom Penh from 30th March to 2nd April 2015 under the theme "*The Future of Biodiversity in Tropical Asia: Addressing Local and Global Challenges.*"

The ATBC meeting will bring together researchers, students, biodiversity specialists, conservation practitioners, policy makers, universities, government agencies and NGOs from around the Asia-Pacific region. It is hoped that the meeting will help to achieve a number of objectives:

1. To promote and improve cooperation, communication and interchange among all people interested in the study, conservation and/or management of any of the components and/or processes present in tropical ecosystems of the Asia-Pacific region.
2. To provide a space where the most recent findings related to tropical biology and/or conservation can be presented and discussed, to catalyse further advancement.
3. To encourage and facilitate research in all aspects of tropical biology and conservation.
4. To support the education of students at both undergraduate and graduate levels, as well as to assist them in the development of their careers.
5. To acknowledge and honour the work of researchers who have had an outstanding long-term impact on

the development of tropical biology and/or conservation.

6. To promote awareness in the general public of the importance of studying and conserving tropical ecosystems.
7. To link ATBC with conservation initiatives in Cambodia and the Asia-Pacific region.

This Special Issue of the *Cambodian Journal of Natural History* presents the abstracts from 223 original talks and posters that were selected for presentation at the meeting. They fall under four broad themes and 15 symposia relevant to the study, preservation and sustainable use of tropical biodiversity in Cambodia or the Asia-Pacific region:

1. Landscape scale conservation

1a) Developing innovative and cohesive approaches for the conservation of Southeast Asia's Critically Endangered species

The aim of this session is to catalyse effective conservation of Southeast Asia's Critically Endangered species, identified as a global priority for averting imminent species extinctions. We will introduce the IUCN SSC Asian Species Action Partnership and demonstrate how innovative approaches have benefitted the conservation of the region's Critically Endangered species.

1b) Assessing and enhancing the resilience of the Southeast Asian protected areas network

We aim to review some of the main threats to the effective maintenance of biodiversity within protected areas, including grazing, fires, encroachment and hunting. We will conduct a gap analysis and assess how well biodiversity is represented in protected areas throughout Southeast Asia, and suggest areas that should be protected to maintain connectivity in the future. We will also review management strategies and effective practices to combat the threats to protected areas throughout the region.

1c) Monitoring rare or elusive species in challenging environments

The aim of this session is to highlight examples of where the inherent challenges to implementing reliable monitoring programmes in the tropics have been overcome through a combination of adapta-

tion, innovation and persistence, and to identify gaps where further methodological advances are needed most.

1d) Moving beyond integrated conservation and development: making incentives work for conservation

Participants will identify conditions that can be used to design conservation incentive schemes that will give community members opportunities to make informed choices about natural resource use, the means to use natural resources sustainably, and the motivation to choose to do so, leading to improved protection of habitats and wildlife.

1e) Local and global challenges to conserving threatened tropical marine mammals in Asia

This symposium will discuss case studies aimed at protecting marine mammals living at the sharp edge of the human interface and on finding solutions to prevent the extinction of populations and species.

2. Species and environment

2a) Fig trees and associated animals

Fig trees and their associated animals are model systems for co-evolutionary studies. This session will highlight the diversity of current research being carried out in the region, including taxonomy, pollination, gene flow and seed dispersal.

2b) South and East Asian savannas: poorly understood and under threat

This symposium comprises a review of what is known about the biodiversity, ecology and conservation status of the remaining savannas in South and East Asia, and where research efforts should be focused in the future.

2c) Understanding and conserving the diversity and ecology of Southeast Asian bats

We review the threats facing bats, the methods being implemented to combat these threats, and the implications that changes in bat diversity may have for the ecosystems that depend on them.

2d) Latitude–altitude gradients: inferring the effects of climate change on biodiversity

Climate change is stated to be a global threat to biodiversity, yet without understanding the distribution of

species and their responses on more local scales, we cannot predict the potential effects of climatic change. Such an understanding is necessary to develop the most appropriate conservation plans.

3. Novel technologies in conservation

3a) Knowing but not seeing: non-invasive DNA sampling for monitoring Asia's threatened biodiversity

Non-invasive genetic sampling is increasingly used to detect and monitor some of tropical Asia's most threatened species. This session explores the uses and potential applications of non-invasive genetic sampling for field conservation biologists in tropical Asia.

3b) Ex situ plant conservation in tropical Asia

This session focuses on the collection, breeding and re-introduction of threatened plant species in tropical Asia. It reports on best practice and interdisciplinary tools to improve the capacity and efficiency of ex situ conservation in botanic gardens, seed banks, tissue culture collections, arboreta and nurseries.

3c) Evolution and biodiversity in tropical Asia

This symposium explores the interface of evolutionary and biodiversity research, and highlights some of the advances in which evolutionary insights can deepen our understanding of natural communities of animals and plants, with a focus on Asia.

4. Supporting humans and biodiversity

4a) Conservation education: building capacity for conservation in Southeast Asia

Southeast Asia is a global conservation priority area, yet for conservation to work in practice requires education and capacity building at all levels. Here we review case studies at various levels to develop best practice guidelines to help secure a future for biodiversity across Southeast Asia.

4b) Continued conflict or co-existence: human impacts on primate behaviour and ecology

Using case studies from across Indochina, this symposium will investigate and discuss the true impacts of humans on primate behaviour and ecology. This is

an important, yet rarely discussed aspect of primate conservation.

4c) Achieving emission reductions under each element of the REDD+ scheme

This session is designed to discuss activities undertaken to reduce carbon emissions or increase carbon stocks in forests.

A total of 52 talks and posters are contributions from Cambodians, scientists or conservationists based in Cambodia and so make a significant addition to the body of knowledge about biodiversity and conservation in this country. Other papers discuss studies from other parts of the Asia-Pacific region that raise topics and issues relevant to Cambodia.

On behalf of the ATBC Asia-Pacific Chapter I thank the editors of the *Cambodian Journal of Natural History* for this opportunity, and hope that you thoroughly enjoy reading this Special Issue.

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Abstracts from the 2015 Annual Meeting of the Association of Tropical Biology & Conservation: Asia-Pacific Chapter

This section contains the abstracts of oral presentations and posters prepared for the Annual Meeting of the Association of Tropical Biology & Conservation: Asia-Pacific Chapter in Phnom Penh, Cambodia, 30 March to 2 April 2015. Abstracts have been lightly edited for length and clarity by the symposium organisers and the journal editors. The order of abstracts follows the agenda of the ATBC meeting at the time of going to press. We apologise to any authors whose abstracts have been inadvertently missed out or assigned to a different symposium.

The Plenaries

Flying fox (Pteropodidae) movement and their role as vectors of ecological good and human suffering in complex landscapes

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The movement of individual organisms is fundamental to the outcomes of ecological processes and to the dynamics of individual populations. As a consequence, individual movement is a driver of many conservation management issues and solutions to these issues will lie, at least in part, in our understanding of individual movement. Flying foxes are a common component of the fauna of moister habitats of the Indo-Pacific and Old World tropics and subtropics, and their frequent association with humans has led them into conflict in many regions. Flying foxes frequently raid fruit crops, they are known vectors of a variety of emerging infectious diseases and of invasive plant species and they are increasingly associated with impact on amenity in urban areas. This has resulted in their persecution across their range and many species are currently threatened. Our response to flying fox impacts and our evaluation of their ecological role has occurred largely in isolation of an understanding of their movement. This has been a huge mistake. In this paper I review our research into flying fox movement in Australia and consider how the scale of their movement influences their ecological role as dispersers of pollen, seeds and disease, and how it impacts on our ability to manage their impacts as well as the flying foxes themselves.

Frontier of plant functional ecology in the tropics: from understanding biodiversity to sustainable forest use

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Since the dawn of plant ecology and biogeography, researchers have sought mechanistic explanations for the relationships between plant species distribution patterns and environmental factors. Certain traits that confer tolerance to extreme temperatures, drought, flooding, edaphic stresses, etc. clearly limit species distribution in relation to large scale environmental variations associated with latitude, altitude, topography and soil types. Yet these are not sufficient to explain coexistence of many species within a given tropical community. So more recently, researchers have focused on traits associated with differences in demographic variables such as growth, survival and population dynamics among coexisting species. In species-rich tropical forest communities, in which many species are rare, it is impossible to adopt the species-based analyses of community assembly developed for temperate plant communities. Thus, a functional-trait approach has become popular as a potentially tractable alternative to understand forest community dynamics, possibly in association with phylogenetic considerations. Indeed, analyses during the last few decades show that commonly measured traits, such as leaf mass per area, tissue density of stems and leaves, seed mass and maximum tree height, show convergent patterns of association with demographic differences and habitat specialisation patterns. These traits are also shown to be associated with species positions along secondary succession, and may contribute to the intelligent design of restoration strategies for degraded forests. Yet these popular, easy-to-measure traits explain only a limited proportion of

demographic variation. Why? What is to be done next? Trait-based ecology is at a critical junction to remain viable for both basic and applied research.

The extinction crisis and the effectiveness of protected areas in Southeast Asia

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Southeast Asia has the highest proportion of globally threatened mammals, birds and reptiles. Human population expansion and accompanying rapid economic growth have resulted in extensive loss of natural forest cover and high demand for wildlife. Overall, increased accessibility of forests, the widespread availability of sophisticated hunting tools and improved communication networks have facilitated the commercial-scale exploitation of species. Poaching and fishing are directly responsible for 40–50% of all threatened land and freshwater vertebrates in 11 ASEAN countries. The imminent extinction of species in Southeast Asia draws attention to the role of protected areas as a core strategy for conserving threatened species. Existing evidence points to the inadequacy of protected areas in terms of size, representation and effectiveness. We review the evidence for species extinctions from within protected areas and provide a contextual analysis of why protected areas in Southeast Asia may fail to protect species on the brink of extinction. The talk will outline key challenges associated with averting the extinction of critically endangered species in Southeast Asia. Understanding what needs to change for protected areas to represent an effective mechanism for species conservation is a critical step in developing a comprehensive strategy for the recovery of threatened species in Southeast Asia.

Recent herpetofauna research in Cambodia: taxonomy is the first step for conservation

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As one of the biodiversity hotspots in Southeast Asia, Cambodia contains a number of important conservation areas. These include mountainous evergreen forest in the Northeast and Southwest, with the highest peak reaching up to 1,771 m, dry deciduous forest in the northern and eastern plains, flooded forests in the Tonle Sap and Mekong River floodplains, and coastal areas along the Gulf of Thailand. Every area supports high diversity of animal species that are not well known to science due to three decades of civil conflict. Among these, herpetofauna knowledge is lagging behind that of neighbouring countries. Although herpetofaunal research began in the 1850s, only a few sites have received post-conflict field investigations. The primary objective of this talk is to present the outcome of recent herpetological research in Cambodia with an emphasis on new discoveries and their importance for conservation. Information on herpetofauna is assembled from various published sources and specimen data from zoological collections. At present, there are 147 known species of reptiles and amphibians, of which 40 are listed on the *IUCN Red List of Threatened Species* as globally threatened, including some of the newly described species. Inventories help decision makers know which species exist, identify areas of endemism, understand species abundance and rarity, know where and in which habitats they occur, which species are under threat, and which need immediate conservation interventions. The growing number of herpetofaunal discoveries indicates that our current check list is incomplete, not to mention there are many gaps in our knowledge of the biology and ecology of the species that have been identified.

Ten lessons for conservation education from 10 years of the MSc in Biodiversity Conservation at the Royal University of Phnom Penh

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Lack of human capacity, particularly in tropical developing countries, is a major impediment to conservation. Tertiary education can increase capacity, yet in developing countries this sector is often weak. Cambodia is rich in biodiversity and lies at the heart of the Indo-Burma Hotspot. However, at the turn of the 21st century, increasing

and uncontrolled economic development threatens its biodiversity and the country lacks the human capacity to manage these threats. Capacity development was severely constrained by a sub-standard education system still reeling from the Khmer Rouge genocide in the late 1970s. To address this, Fauna & Flora International and the Royal University of Phnom Penh established Cambodia's first Masters of Science degree—the MSc in Biodiversity Conservation—in 2005. The achievements of the programme include 56 students who have completed the course, publication of the *Cambodian Journal of Natural History*, and the establishment of a zoological museum and herbarium. Reviewing 10 years of the programme, I identify 10 'lessons learnt' for conservation education: (1) Know your history, (2) Partner well, (3) Set the right standards, (4) Attract and keep students, (5) The pros and cons of scholarships, (6) Donors: nothing lasts forever, (7) Watch for changing student demographics, (8) Institutional building: not for the faint of heart, (9) Everyone wants to be your friend, but choose your friends wisely, and (10) Know when it is time to go. I hope these lessons will assist in the implementation and development of other conservation education programmes.

Welcome to the Anthropocene!

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The term Anthropocene is used to refer to the current time period in which human impacts are at least as important as natural processes. A working group of the International Commission on Stratigraphy is now considering whether the Anthropocene should become a formal part of the geological timescale, following on from the Holocene. While there is broad agreement that many key environmental parameters are now outside their Holocene ranges as a result of anthropogenic impacts, it has been difficult to agree on a starting date for the new epoch. Whether formalised or not, however, the concept of a world changing rapidly, directionally, unpredictably and irreversibly under human pressures has already had consequences for how ecological research and conservation management are—or should be—conceptualised and conducted. Ecologists can no longer ignore the human-modified ecosystems that increasingly dominate the planet, and conservationists can no longer focus on keeping things the way they were, or restoring them to the way they used to be. The basic goals of conservation remain the same—preserving biodiversity and maintaining ecosystem services—but the methods will have to be adapted to the realities of a changing world. New data sources are emerging (such as remote sensing and next generation sequencing) and new methods of global collaboration are being developed, but traditional field skills are needed more than ever.

Mathematics in the jungle: informing tropical conservation with quantitative theory

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In 1760 the mathematician Daniel Bernoulli wrote, "I simply wish that, in a matter which so closely concerns the wellbeing of the human race, no decision shall be made without all the knowledge which a little analysis and calculation can provide." He wrote this in the context of smallpox inoculations, but his remark applies equally well to conservation biology in the 21st century. I will review some case studies of successful mathematical models in conservation biology, including recent models we have developed for estimating undetected extinctions and to explain species richness on small islands. I will conclude by pointing out that the Asia-Pacific region leads the world in high school mathematics and science education, but also faces severe conservation challenges. Therefore we should be encouraging more mathematically-talented youngsters from the region to move into ecology and conservation biology.

Behavioural ecology and conservation of Asian elephants in Sri Lanka

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Despite an association with people over more than five millennia, the behaviour of wild Asian elephants *Elephas*

maximus has been relatively poorly understood. Its cryptic nature, the inaccessibility of its habitats, and lack of emphasis on behavioural research in its range states may all contribute to a view of elephants that is primarily based on research in Africa. However, the two genera *Elephas* and *Loxodonta* are separated by two continents and over six million years of evolution. Recent field studies in Sri Lanka challenge long-held views about the social behaviour of Asian elephants, demonstrating significant differences from the African species. These include the dynamic nature of social relationships among females, vocal behaviour, space use, and modes of resolving social conflicts. These findings offer exciting new insights into the social world of Asian elephants, while the species is concurrently threatened by a host of conservation challenges. Here too, the sister species differ: habitat loss and spatial constraints being the primary source of threat to Asian elephants, while ivory poaching comes as a secondary consequence. Understanding elephant behaviour is as essential to addressing these issues and ensuring the species' long-term survival as gathering basic data on elephant abundance and distribution: itself a great challenge. To answer these challenges, greater investments in basic research and long-term monitoring with appropriate scientific tools are needed so that elephant conservation can be better informed through evidence.

Can secondary forests really save tropical biodiversity? A case study from tropical Australia

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Tropical forest clearing and later abandonment is considered one of the most important factors governing the fate of the world's terrestrial biodiversity. The recovery of plant diversity in secondary forests can be slow because there are strong ecological and environmental barriers to the regeneration process. We examined the spatial dynamics of forest regeneration relative to marginality and remnant primary forest in a 3,000 km² pastoral region in tropical Australia. Subsequently, floristic composition and terrestrial carbon accrual were investigated along successional forest chronosequences. We found the extent and distribution of secondary forest was overwhelmingly influenced by the proximity and size of primary forest fragments. Some 85% of the secondary forest area occurred <1 km from primary forest, and 86% of secondary forest patches >50 ha were <400 m from primary forest. Along our successional forest chronosequences of 4–60 years, we found forest carbon accrued rapidly towards primary forest levels, but floristic diversity was still limited, with certain functional groups lacking from the community. Our findings underscore the need to conserve even modest rainforest patches in agricultural landscapes, and show that the recovery of floristic diversity in successional forest is gradual and protracted.

Tropical logging and roads: avoiding a fatal synergism for forests

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Industrial logging is one of the most widespread land uses in the tropics, with lands in various types of logging reserves now encompassing some 400 million hectares—an area larger than Mexico and Indonesia combined. If allowed to recover naturally, selectively logged forests can support considerable biodiversity, carbon storage, and natural hydrological services. Unfortunately, many logged forests are quickly invaded by illegal hunters and colonists that seriously degrade or destroy the forest. A key problem is the extensive networks of forest roads created by loggers, which greatly facilitate forest invasions. I will highlight a series of policy recommendations and strategies to limit the damage wrought by large-scale logging and its secondary effects, and underscore the importance of conserving logged forests across the tropics.

Protecting the lesser carnivores: diversity and conservation of small carnivores in Sumatra

Wulan PUSPARINI

Wildlife Conservation Society, Indonesia.

Conservation funding and politics are often driven by big charismatic carnivores, such as tigers, and hence less protection and research occurs on their lesser known relatives. Using unconstrained ordination, we explore the

diversity of small carnivore species in southern and northern parts of Sumatra. The dataset was bycatch from a six-year camera-trapping tiger survey in Bukit Barisan Selatan National Park, southern Sumatra, 1998–2004, and two years (2010, 2013) of camera-trapping in Gunung Leuser National Park, northern Sumatra. We found 11 species of small carnivores: *Arctictis binturong*, *Arctonyx hoevenii*, *Cynogale benenettii*, *Hemigalus derbyanus*, *Herpestes semitorquatus*, *Martes flavigula*, *Mustela lutreolina*, *Mydaeus javanensis*, *Paguma larvata*, *Paradoxurus hermaphroditus*, and *Prionodon linsang*. We were interested in extracting dominant, underlying gradients of variation among small carnivore species from a set of environmental variables. The interdependent dataset comprised five environmental variables (kernel density of road and river, distance to nearest village, roughness, and deforestation rate). Species relative abundance data were fitted on the final biplot as a preliminary/exploratory analysis to seek the species–environment relationship. Understanding how these species interact and which environmental gradients affect them are necessary for designing their conservation initiatives and protection.

The amazing world of bats and a novel view of conservation

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More than 1,300 species of bats comprise one-fifth of all mammals. They live nearly everywhere and provide essential eco-services, including billions of dollars of savings through avoided pesticide use, food and fertiliser production and forest propagation. In Southeast Asia, bats are key pollinators of economically important crops, such as durian and petai, and a wide variety of timber and other products come from trees and shrubs that rely on bats for seed dispersal. Large aggregations of cave-dwelling bats throughout Southeast Asia could be of substantial economic importance if protected or reestablished, as illustrated by progress at Khao Chong Pran Cave in the Ratchaburi Province of Thailand. Since game wardens were hired in 1982, the bat population (largely *Chaerephon plicatus*) has grown by millions, and by 2002, annual guano sales for fertiliser rose from 12,500 U.S. dollars to 135,000. These bats, while harming no one, also consume tons of white-backed planthopper pests of rice and attract thousands of tourists who benefit local vendors. Thousands of nectar-feeding bats (*Eonycteris spelaea*) also pollinate durian and petai. Studies documenting the full economic impact of such conservation are urgently needed, providing powerful incentives for local communities and national governments to protect and restore bat colonies that are seriously threatened by careless quarrying and overharvesting for food. Such human-benefit-centred approaches can provide ideal entry points for broader conservation efforts for endangered species.

LANDSCAPE SCALE CONSERVATION

Symposium—Developing innovative and cohesive approaches for the conservation of Southeast Asia's Critically Endangered species

Conservation and research needs for Critically Endangered Mekong megafauna

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The Lower Mekong (Thailand, Laos, Cambodia, and Vietnam) supports four of the six largest freshwater fish species globally. Three of these species (giant carp *Catlocarpio siamensis*, Mekong giant catfish *Pangasianodon gigas* and dog-eating catfish *Pangasius sanitwongsei*) are IUCN-listed as Critically Endangered with a fourth (giant freshwater stingray *Himantura chaophraya*) listed as Endangered. All four are poorly known and threatened by

unsustainable exploitation and severe ecosystem alteration. Understanding their current distribution and status is critical for establishing effective conservation actions and advocacy against unsustainable infrastructure projects. Our research on these species used a combination of Local Ecological Knowledge (LEK) from fishing communities and innovative environmental-DNA (eDNA) sampling to clarify their trends and status. Interviews were conducted in six villages in Siphandone, southern Laos, to establish the mean last sighting date for six species of endemic Mekong fish including the Mekong giant catfish and dog-eating catfish. Mekong giant catfish, although known by all fishermen, had a significantly less recent last sighting date than other threatened species, indicative of a substantial population decline in support of the species' Critically Endangered status. Environmental DNA surveys across the species' range, and ichthyoplankton analysis at known former spawning grounds on the Laos–Thai border, produced a single Mekong giant catfish record from the mainstream Mekong River north of the proposed Xayburi Dam. Unless all Mekong mainstream dams are suspended, and effective enforcement is established at all potential spawning grounds, the future of this enigmatic flagship for Mekong freshwater biodiversity is bleak.

Conservation of Bengal florican *Houbaropsis bengalensis* in a farming landscape

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The Asian bustards (Otidae) are a very threatened group. All occupy grassland environments, which are under intense pressure for human use. In this context it is no surprise that three of the five species, including the Bengal florican, are Critically Endangered. The Bengal florican now numbers fewer than 1,000 birds, found disjunctly on the terai of Nepal and India and the Tonle Sap floodplain of Cambodia. More than two-thirds of the population is in Cambodia, where numbers of displaying males have dropped by 44–64% from 2005/7–2012, to 216 (95% CI 156–275). Initially, hunting was the greatest threat, but this has been brought under control and it is rapid conversion of grassland and traditional agriculture that has led to the recent population decline. The Wildlife Conservation Society's Cambodia Program has been protecting Bengal floricans for more than 10 years. The conservation interventions employed straddle the land sharing–land sparing paradigm, whilst our monitoring has revealed trends in key breeding sites. In the site where most conservation interventions have been focused the population is stable. At that site, we have encouraged traditional human uses of the grassland that are compatible with Bengal florican conservation, while helping local people to resist land-grabbing attempts by external companies that destroy large swathes of florican habitat. There is a need to expand conservation interventions to other sites, which will require careful evaluation of opportunities and conservation approaches to ensure success.

Conservation of Critically Endangered white-shouldered ibis *Pseudibis davisoni* in Cambodia's Mekong flooded forest

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The Mekong flooded forest is alongside the mainstream Mekong in the Cambodian provinces of Kratie and Stung Treng. A population of the Critically Endangered white-shouldered ibis *Pseudibis davisoni* occurs in this area. Monitoring of the species started in 2009 with a nest protection programme through which local people were paid to protect bird nests. The project engaged the local community by paying them to conduct roost counts four times every year during the rainy season from July to October. In 2014, the national annual census recorded 892 birds in five protected areas. The Mekong flooded forest supports the third largest white-shouldered ibis population in Cambodian protected areas with 170 individuals: approximately 20% of the national total recorded in 2014. Eighty-three chicks fledged over five seasons from 53 nests; a success rate of 60%. The mean number of chicks per nest was 2.08. Forty-seven percent of nest failures were due to anthropogenic disturbance and robbery. Twenty-three percent of nest failures were due to eggs falling from nests. Predators were also a problem with 16% of nest failures due to predation. Robbery from nests by local people has been eliminated since 2012: this might be a result of increased local awareness through the bird nest protection programme. Our study suggests the Mekong flooded forest is highly significant for white-shouldered ibises and other globally threatened large water birds.

Development of a multi-stakeholder technical working group for the Critically Endangered Cat Ba langur *Trachypithecus poliocephalus*

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The Cat Ba langur *Trachypithecus poliocephalus* is one of the most threatened primate species globally, having been reduced to approximately 60 animals in the wild and five in captivity. The in situ population currently comprises an estimated 65 animals in only two breeding populations: the Cua Dong/Viet Hai population and the “Sanctuary” population. The ex situ population comprises five individuals that are descended from only two founders. Given the precarious status of the species, the fragmented nature of the population, the lack of integration between the in situ and ex situ populations, and the large number of stakeholders that include local authorities, protected area managers, conservation NGOs and central level decision makers, a coordinated multi-stakeholder working group was set up to discuss and strategize on issues relating to conservation management. The Cat Ba Langur Technical Working Group has a vision, objectives, regulations and a standing membership including a steering committee. Early meetings have focussed on building consensus concerning population management to reduce extinction risk and move towards a ONE Plan approach. Based on early success, the model is being considered for replication for all of Vietnam’s primates by the Government of Vietnam.

Evaluating the status of an inter-basin translocation of four species of endemic Sri Lankan fishes

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In 1981, four species of fish (*Pethia cumingii*, *P. nigrofasciata*, *Puntius titteya* and *Rasboridaes vaterifloris*) endemic to streams in southwestern Sri Lanka were translocated to five streams around the Nawalapitiya area of the Mahaweli River Basin, namely the Balantotaela, Ceypothaela, Horakadaela, Kahawaturaela and Walapitaela. The present study aimed to evaluate the status of these populations. Sampling sites were based on the original translocation sites. Sporadic sampling was carried out in the Mahaweli River to determine species presence. Seining was carried with an equal sampling effort of 15 minutes for each station. *Pethia cumingii* has undergone taxonomic revision, and from this study it was confirmed in the Kelani Basin that the species translocated was *P. reval*, not *P. cumingii*. All of the translocated species had well-established populations. *Pethia nigrofasciata* was the most abundant and was found in all of the main sampling sites except in the Ceypothaela. It was also observed that *P. nigrofasciata*, *P. reval* and *R. vaterifloris* had expanded their ranges by dispersing to nearby streams. *Pethia titteya* was confined to the Ceypothaela, but *P. reval* had spread to the main Mahaweli River and was recorded from the Gelioya and near the Gampola area. *Channa orientalis*, which was found in the Ceypothaela, may have been introduced as a non-target species. The translocations can be considered successful although there were some drawbacks.

Fear in the forest: understory avifauna exhibits heightened risk perception in degraded tropical forest

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Understanding how biodiversity and ecosystem functions are maintained in degraded tropical forest is of high research and conservation significance. Our understanding of how ecological processes may be affected by tropical forest degradation remains painfully scanty. Predator–prey interactions are one class of ecological processes with high ecological and evolutionary significance and may be markedly altered by habitat degradation. In this study we ask how can habitat degradation affect predation-risk perception—an important aspect of predator–prey interactions that closely reflects predation pressure and defines prey decision-making under risk-related situations. In the lowland rainforest of Sumatra, we tested whether vegetation structural changes following selective

logging significantly altered the risk perception of understorey birds. We experimentally elicited avian predator-mobbing behaviour to quantify avifaunal risk perception along a gradient of habitat degradation. Understorey gleaning birds exhibited elevated risk perception in degraded forest compared to primary forest, in association with alterations in vegetation structure rather than the distribution of major predator species. In comparison, risk perception of understorey sallying species did not seem to be affected by forest degradation. We conclude that tropical forest degradation, as manifested in vegetation change, heightens avian risk perception at the community level in our study system in ways that can potentially influence vital processes defining animal community structure. Our work thus suggests fertile avenues for revealing and managing ecological processes underlying tropical biodiversity persistence in degraded tropical forests.

Forgotten heroes of the Asian forest

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Asia encompasses some of the world's greatest biodiversity. It is home to several endangered species, such as tigers, Asian elephants, rhinos, red pandas and orangutans. The region is also home to 60% of the world's human population. Most of this biodiversity is under immense pressure due to unsustainable practices and demands on wildlife and on their products. There are committed men and women protecting our endangered species, forests and national security, working in remote areas, often in difficult and dangerous conditions. Rangers are the most important conservation stakeholders yet their voices are largely ignored and their efforts are often unrecognised. Unfortunately, reports show that 66% of rangers across Asia are not adequately trained and 64% lack even basic equipment such as patrol boots. Because there was no ranger association in Asia to help address these and other issues, to get rangers the recognition they so richly deserve, and to bridge the gap between the international and Asian ranger community, WWF Tigers Alive Initiative (TAI) established the Ranger Federation of Asia (RFA) in July 2013. Currently, the RFA has more than 1,500 members from five countries: Nepal, Cambodia, China, Myanmar and Indonesia. Over the last few months, the RFA has discussed with the International Ranger Federation, TGLF, the PAMS Foundation and WWF the need to highlight the situation of rangers in Asia, to standardise equipment lists to aid donors, and to draft basic welfare standards to present to the various conservation agencies. It is time that these rangers were no longer forgotten.

Habitat enhancement project for the Critically Endangered Hainan gibbon and its implications for large-scale forest restoration in Indochina

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The Hainan gibbon *Nomascus hainanus* is endemic to China's Hainan Island and is one of the most endangered primate species in the world. The tiny population of 20-odd gibbons is restricted to Bawangling National Nature Reserve and is essentially trapped in an isolated patch of primary montane rainforest c. 15 km² in size, surrounded by young forest, pine plantation and human-dominated landscape in the foothills. To expand the gibbons' habitat, a habitat enhancement project was launched in 2005. The aims are to: (1) Reconnect fragmented gibbon habitats; (2) Restore degraded lowland habitat for gibbon use; and (3) Increase the density of gibbon food plants so as to improve the gibbon carrying capacity of the forest. The enhancement project included establishing a native tree nursery, and planting and nursing saplings. From 2005 to 2008, over 80,000 saplings of over 50 species—the majority of which were gibbon food plants—were planted in 163 hectares of degraded foothills adjacent to existing gibbon forest. Twenty plant species were found to have survived in a survey in 2013. Among the 20 surviving plant species, the best-performing were *Acmena acuminatissima*, *Bischoffia javanica* and *Baccaurea ramiflora*. We believe the results from our restoration experiment have significant implications for large-scale forest restoration in other areas of northern Indochina with similar floristic, climatic and socio-economic conditions. The methodology of seed collection, planting and nursing, as well as future improvements will be discussed.

Integrated in situ and ex situ conservation has prevented the extinction of the southern river terrapin *Batagur affinis* in Cambodia

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Tortoises and turtles are among the world's most threatened vertebrates. Seventeen of the world's 25 most endangered tortoises and turtles are found in Asia. The southern river terrapin *Batagur affinis* is one of the rarest in the world: perhaps fewer than 400 adults survive globally in Cambodia, Thailand, Peninsular Malaysia, and Indonesia (Sumatra). The species was presumed extinct in Cambodia until 2001, when a small population was discovered along the Sre Ambel river in Koh Kong Province. Since then, the Wildlife Conservation Society (WCS) and the government's Fisheries Administration have worked in partnership, together with local communities, to conserve this terrapin, which is known as the royal turtle and recognised as Cambodia's national reptile. We protect and monitor nests, and head-start hatchlings in a locally managed facility with more than 180 individuals. In 2015, we will release 25 individuals to boost the wild population: every individual will be monitored using acoustic-telemetry to understand their post-release dispersal and monitor their survival. We have recently designed a purpose-built centre to continue the head-starting programme, begin breeding terrapins in captivity and maintain an insurance colony until the status of this species is more secure in the wild. These in situ and ex situ methods have safeguarded this species from extinction in Cambodia to date and will hopefully enable its recovery.

Investigating the use of camera trapping to quantify illegal human activity in three protected areas of the Sundarbans, Bangladesh

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Asian biodiversity is increasingly dependent on the existing network of protected areas. Three wildlife sanctuaries in the Bangladesh Sundarbans are examples of Asian protected areas where the detection of human disturbance is difficult due to inadequate numbers of patrol staff relative to the size of the mangrove forest that requires monitoring. The aim of this study was to use camera traps in the three sanctuaries to quantify: (1) the levels of different types of illegal human activities; (2) their spatio-temporal variation; and (3) what proportion of camera trap photographs can be used to identify perpetrators. Every photograph of an illegal human activity (IHA) was based on the Bangladesh Wildlife (Conservation and Security) Act 2012 and categorised by the types of equipment observed. Likewise, legal human activity (LHA) was categorised as patrolling or wildlife viewing, based on the type of boats or equipment visible. A total of 914 unique human activity events were recorded, of which 872 were IHA and 42 were LHA, during a total of 1,039 trap nights. The best model suggests that during the spring tide, IHA occurred in 91% of camera-trapped locations in the West during the survey period, while IHA occurred in 84% and 74% of locations in the South and East areas of the sanctuary respectively. Camera trapping in remote areas can potentially help protected area managers to increase rates of detection of IHA in their landscapes and so increase rates of arrests and prosecutions with proper evidence.

Modelling globally Endangered black-faced spoonbill population viability under environmental change

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The black-faced spoonbill *Platalea minor* is an iconic Endangered species distributed across most of East Asia. Its population has suffered a severe decline and only a few hundred individuals were estimated globally in the 1990s.

Extensive monitoring and conservation interventions have aided a substantial recovery of the species, and 2014 estimates put the global population at approximately 2,700 individuals. While impressive, this is significantly smaller than the 4,000±950 individuals predicted for 2014 by a Population Viability Analysis (PVA) conducted in 2004. Using a variety of new population data in a revised PVA, we found that spoonbill age of maturity, fledgling success and fecundity affect estimates of population size. In particular, re-projecting from 2004 to 2014 using the revised PVA, we estimated a final population size of 2,850±200: a range that includes the observed population count (2,700) in 2014. Using this PVA in conjunction with spoonbill species distribution models, we are developing spatial models of population change that enables the evaluation and ranking of species threats including habitat loss through development, climate change and disturbance. The results of this research will inform management plans for the black-faced spoonbill in Asia while also providing a much needed case study on the impacts of change on a widely distributed Endangered species in the region.

Selamatkan Yaki: saving the Critically Endangered Sulawesi crested black macaque in an anthropogenic landscape

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Selamatkan Yaki (SY, Save the Macaques) is an education, research and conservation programme focused on protecting the Critically Endangered Sulawesi crested black macaque *Macaca nigra* and its native habitat in North Sulawesi, Indonesia. Due to habitat loss and hunting (primarily supplying a luxury market), these endemic primates have experienced population declines of over 80% in the past 40 years. Typifying an anthropogenic landscape, the range of *M. nigra* is highly fragmented and generally of poor quality. SY is currently working to protect the remaining *M. nigra* population through protected area management, education and awareness raising campaigns and improving ecotourism infrastructure. Future efforts aim to optimise low-tech agricultural techniques and develop alternative livelihood strategies that can be successfully maintained with minimal input and/or low disturbance of the dwindling local forests. A key focus of SY activities and a current PhD study, has been the recognition that local people are vital to *M. nigra* conservation. Considering the anthropological causes of *M. nigra* decline is fundamental in the creation of threat mitigation strategies. Thus far, a successfully adopted two-step approach that empowers local role models—ranging from religious leaders, youth representatives and celebrities—has enabled social diffusion of the conservation message and assisted in removing barriers to effective behaviour change. Lessons learnt from SY provide an insight into the causal links between advocacy and values-oriented support for conservation activities in an anthropogenic landscape, and our understanding of advocacy mechanisms may enhance in situ conservation strategies.

Threats to biodiversity from forest conversion

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Global change is known to dramatically affect the diversity and composition of amphibians, particularly in the tropics. However, human-driven impacts on functional diversity and trophic interactions are largely unknown. Here, we analysed shifts in trophic position and functional and phylogenetic diversity of Southeast Asian stream-dependent anuran amphibians across a disturbance gradient from primary forest through intensively logged forest to oil palm plantation. We determined the diet composition of 59 anuran species by means of stomach flushing. We also used the diet composition of species as estimates for species traits to calculate their functional diversity. The trophic position of the entire anuran community was elevated in heavily disturbed habitats, whereas species phylogenetic, dietary, and functional diversity were reduced. However, beyond the effect of decreased species richness, only phylogenetic species variability and functional diversity were significantly affected by land conversion, indicating a non-random loss of phylogenetic groups and functionally unique species. Overall, the observed changes in species interactions and functional composition suggest a massively modified role of

anurans in altered habitats and a major reorganisation of food webs. Such far-reaching changes to the way species groups interact are likely to threaten local biodiversity and ecosystem functioning in heavily disturbed natural habitats and particularly in human-modified habitats. On the upside, we show that small-scale riparian reserves are able to mitigate the negative consequences of land conversion considerably.

Saola *Pseudoryx nghetinhensis*, serow *Capricornis sumatraensis*, and sambar *Rusa unicorn* ecology according to interviews of local people in Lao PDR

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The problem with very rare species, such as saola *Pseudoryx nghetinhensis*, is that monitoring techniques do not provide enough data to estimate occupancy, but interview data can be successfully used to evaluate their distribution in the landscape. Our objective was to assess the distribution and macrohabitat characteristics of saola, serow *Capricornis sumatraensis* and sambar *Rusa unicorn* in and around Phou Sithon Endangered Species Conservation Area through interviews with local people. Using maps, local people were asked to mark down places where they had observed saola, serow and sambar. ArcGIS was then used to characterise variables including elevation, slope, forest type, and distances from streams/rivers, roads, villages and human disturbance associated with each observation. Serow detected using camera traps were also compared with serow reports from local people (there were no saola or sambar photo records). The locations of camera traps that did or did not detect serow were also compared. Serow was found significantly further from roads than saola or sambar. Sambar were significantly closer to villages, at lower elevations, in areas with a lower percentage of forest cover and a higher density of streams than saola or serow. Cameras that detected serow were significantly further from roads and at higher elevations than the serow observations reported by local people. Cameras that detected serow were found at significantly higher elevations than non-detection sites. Sambar appear to be ecologically different from saola and serow, whereas saola and serow appear to be roughly similar ecologically. These findings may assist in searching for possible sites that might harbour the elusive saola.

Ecology and conservation of Endangered dholes *Cuon alpinus* in Southeast Asia

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Dholes *Cuon alpinus*, or Asiatic wild dogs, are the least studied and understood of the Endangered large carnivores in Asia. They have disappeared from >80% of their range during the past 50 years, and there are now <2,500 adult dholes remaining in the wild. I reviewed the current status and distribution of dholes throughout Southeast Asia, and showed that current populations are small and highly fragmented. To better understand their conservation needs, I carried out recent ecological research on dholes in Bhutan, Laos, and Cambodia. Results showed that in Bhutan, dholes have made a comeback in recent years, after being nearly extirpated from the country due to poisoning campaigns. However, current populations are limited by low prey numbers. In Laos, dholes still occur in evergreen forests in the northern parts of the country, but packs were small and preyed on relatively few species: factors that likely limited their population size. My research in the open deciduous forests of eastern Cambodia showed that predation by dholes focused almost exclusively on two common species: wild pig *Sus scrofa* and muntjac *Muntiacus muntjak*. However, the population of dholes in the region is limited primarily by disease transmission from village dogs. Overall, dholes in Southeast Asia appear to be limited by different factors, including a low prey base, human persecution, disease transmission from village dogs, and habitat loss. The future of dholes in the region is dependent on large protected area complexes, where high prey numbers are maintained and access by poachers and village dogs is limited.

Symposium—Assessing and enhancing the resilience of the Southeast Asian protected areas network

Conservation success of Prek Toal Core Area, Tonle Sap Biosphere Reserve, Cambodia

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The Tonle Sap is the largest freshwater lake in Southeast Asia and was designated as a Biosphere Reserve in 1997. The Prek Toal Core Area (21,342 ha) is one of the most important core areas in the biosphere reserve. It supports the largest breeding colonies of large waterbirds in Southeast Asia and is the lake's most productive fishery lot. However, the biodiversity of the Prek Toal Core Area was fragile for years, despite environmental education and awareness-raising initiatives by the Ministry of Environment (MoE). Thousands of waterbird chicks and eggs were collected during the 1990s and waterbird colonies were continually destroyed by the fishing lot owners in that period. Since 2001, however, with financial and technical support from the Wildlife Conservation Society (WCS), MoE rangers have undertaken constant watches of the bird colonies, provided protection for the main streams and implemented SMART. The protection of waterbird colonies and main streams in the core area have resulted in dramatic increases of threatened bird species and fish stocks, improving ecosystem health and benefiting many other species. All key species of large waterbirds in Prek Toal have stable or increasing populations. With government support, local communities actively participate in the conservation programme and ecotourism and they in turn have received benefits from alternative income generation through conservation and ecotourism.

Defending small reserves: a case study on the role of environmental education programmes in protected area development

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Southeast Asia has one of the highest deforestation rates in the tropics. Small-scale reserves can add to protected areas, but are underfunded, leaving them unprotected. We present a case study of a small reserve in Northeast Thailand as a model for incorporating environmental education into planning and development to support small protected areas. To compensate for limited government funding, Sakaerat Environmental Research Station (SERS) has developed a sustainable science camp for schools that incorporates conservation and local cultural knowledge. From its inception in 2002 until 2012, the science camp has generated 5,138,624 Thai Baht (156,775 USD) in supplementary budget. The science camp profits have provided a constant source of income for the reserve while facilitating the main objectives for the Man and Biosphere Reserve (MBR) Programme: conservation, economic development and logistical research support. The ranger corps has garnered a more substantial budget to deter poaching and illegal logging with the advent of the science camp programme. Three major sustainable development projects have been supported by the science camps to provide an alternative income to poaching for the local community. The SERS infrastructure developed for the science camp also provides greater logistical support for conservation research in this reserve than in the other small MBRs in Thailand. The SERS science camp is already fully booked through 2016, hosting roughly 17,000 students per annum to provide a sustainable long-term income. The potential for small reserves to act as outdoor classrooms should be considered when assessing the costs in designing or reinventing small protected areas.

Do communities support marine conservation initiatives in Cambodia? Measuring local perceptions in a proposed Marine Fisheries Management Area

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Social acceptance of Marine Protected Areas (MPAs) is necessary if they are to be effective. The Fisheries Adminis-

tration (FiA) and partners have been developing the Kingdom of Cambodia's first Marine Fisheries Management Area (MFMA)—a type of multiple-use MPA—since 2012. The objective of our socio-economic survey was to provide baseline data to compare and analyse the effects that the MFMA would have on local communities, and to measure future progress towards the specific socio-economic goals and objectives of the MFMA. In December 2014, Fauna & Flora International (FFI) and FiA undertook a survey of 229 families in five villages. Results indicate that 86% of people interviewed believe that the MFMA will be beneficial for the archipelago and its inhabitants. The reasons given for these favourable attitudes were: 45% of respondents believed the MFMA would increase marine biodiversity, 14% believed it would result in a decrease in illegal fishing activities, and 13% thought that the MFMA would increase fishing yields. Other baseline data gathered included family income streams (marine activities, tourism, agriculture, small business, and "other"), household assets as an indicator of wealth, household food security, attitudes and perceptions of resource conditions and threats, awareness of rules and regulations, levels of compliance with respect to the proposed MFMA, and stakeholder participation in coastal management. Results suggest that local villagers are currently generally accepting of the MFMA's establishment. Our data will enable tracking of future changes in perceptions and this survey would ideally be repeated every two years.

Filling data gaps for Cambodian marine habitats: seagrass diversity and distribution in the Koh Rong Archipelago

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Seagrass habitats around Cambodia's offshore islands have been little studied and are under threat from various anthropogenic factors, especially those related to destructive fishing techniques. Field surveys were conducted in 2013 and 2014 during the dry season around both major islands within Cambodia's first proposed Marine Fisheries Management Area (MFMA): Koh Rong and Koh Rong Sanloem. The surveys aimed to evaluate seagrass distribution, abundance and diversity around the islands. We employed transects and quadrats to sample seagrass species richness and percentage cover. The proposed MFMA was found to contain an estimated 18 hectares of seagrass habitat. Four species of seagrass were recorded: *Halodule pinifolia*, *Thalassia hemprichii*, *Enhalusa coroides* and *Halophila minor*. The commonest species was *H. pinifolia*. The highest percentage cover of seagrass was found in areas where the benthos was coarse sand. Results have been used to inform consultations on zoning the proposed MFMA by identifying key areas for protecting the remnant seagrass beds. This study represents the first comprehensive assessment of seagrass species in the Koh Rong Archipelago and provides a baseline for future monitoring.

Grassland conservation supports threatened birds and local people's livelihoods

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Grassland is typically neglected in the protected area networks of Southeast Asia. The grasslands of the Tonle Sap floodplain in Cambodia support about 70% of the global population of the Critically Endangered Bengal florican *Houbaropsis bengalensis*, which only occurs in three countries: Cambodia, India and Nepal. The grassland is important not only for the florican but also for local livelihoods. However, there are a lot of ongoing challenges to protecting the grassland from such development activities as dry season rice farming and degradation. To address these problems, the government's Forestry Administration has cooperated with the Wildlife Conservation Society (WCS) since 2006 to manage and conserve these important grasslands. Six Bengal Florican Conservation Areas were established in 2006. The project has set up an education programme, research and monitoring, law enforcement, and a community management committee (CMC) at each site. The CMCs play a very important role in management because they are recognised by the local authorities and help to monitor and investigate any activities inside the project area; reporting any illegal activities to the project team to take action quickly and prevent any development activities inside the conservation areas. Protecting these grasslands, which flood in the wet season, also contributes to local livelihoods through protecting fish habitat, providing areas for grazing cattle, deep-water rice farming and collecting thatching materials and crickets. Moreover the project has

developed ecotourism based on the floricans and wildlife-friendly rice, which provides an income for community development. As a result the Bengal floricane population is stable.

How can we quantify the impacts of roads on Southeast Asia's protected areas?

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Habitat destruction and overhunting are two major threats to biodiversity in protected areas. The construction of roads can be a catalyst for these two threats. Before conservation strategies can be developed to minimise the impacts of roads, we need to quantify how roads are contributing to the conversion of habitats and illegal hunting in protected areas. In this study, we demonstrate how species distribution models, satellite imagery and animal-sign surveys can be used to provide quantitative evidence of roads causing impacts by: (1) cutting through habitats where endangered mammals are likely to occur; (2) intensifying forest conversion; and (3) contributing to illegal hunting and wildlife trade.

Lessons and challenges in participatory design of multiple-use Marine Protected Areas—a Cambodian case study

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The development of Cambodia's first Marine Fisheries Management Area (MFMA)—a type of multiple-use Marine Protected Area (MPA)—required a comprehensive exercise in stakeholder engagement. The first step was the creation of a provincial government management team, which coordinated the consultation process and developed the necessary provincial legislation to establish management structures. A technical working group was formed, reporting to the provincial government team, and incorporating government authorities, NGOs, island concessionaires, Community Fisheries and tourism agencies (dive companies). In total, 26 individuals were included. The technical working group was responsible for balancing stakeholder needs with conservation initiatives, and for initiating the development of legislation for the creation of the proposed MFMA, which has now been submitted to the government. This integrated approach was designed to ensure effective collaboration and coordination, and enabled stakeholder input to zoning plans. Research and recommendations have been compiled and submitted to the Ministry of Agriculture Forestry & Fisheries to support the proclamation of the Cambodia's first MFMA, and 10 MFMA goals (socio-economic, biophysical, governance) agreed. Monitoring and evaluation will be undertaken through socio-economic surveys, habitat monitoring as well as the MPA Management Effectiveness Tracking Tool. Although time consuming, the importance of collaborative approaches in engaging stakeholders in the development of multiple-use MPAs cannot be overestimated. While the signature for MFMA proclamation is still pending, it is hoped that this participatory approach will yield results in terms of improved marine and coastal conditions, and enhanced socio-economic benefits for local villagers.

Life in the matrix: how can we best protect biodiversity in an increasingly fragmented landscape?

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Across Southeast Asia, many countries meet the minimum requirements for protected area coverage, at least on paper. Yet what does this actually mean for biodiversity, and do these protected areas actually match patterns of biodiversity? Do they reflect patterns of endemism within the landscape, and do they actually protect the biodiversity within them? Here we map patterns of biodiversity, endemism and community assemblage of the majority of vertebrate and plant species across Southeast Asia, and correlate these patterns with eco-climatic and more historic factors. We explore the coverage of these regions by the protected areas network, and highlight

important diverse or unique regions that are currently under-represented (or unprotected) within the protected areas network. In addition, we map protected areas that are known to suffer from significant poaching, or where forest loss warrants further protection in the future. Lastly, we demonstrate how strategically placed afforested corridors could connect parts of the landscape and best protect biodiversity in an uncertain future.

Protecting an unprotected area: a case study of conserving a tropical limestone forest on Hainan Island, China

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E'xianling is the most extensive limestone outcrop on Hainan Island, with good forest cover and diverse vegetation types. Distinctive soil chemistry, hydrology, geology and associated micro-climates of karst landscape contribute to the unique ecosystem of that area. E'xianling has more than one-third of the 397 Hainan-endemic seed plant species, including 26 species that are endemic to E'xianling. Several island endemic vertebrate species can also be found here, such as the Hainan gymnure *Neohylomys hainanensis*, Hainan hare *Lepus hainanus*, Hainan hill partridge *Arborophila ardens* and Bawangling cave gecko *Goniurosaurus bawanglingensis*. For various reasons, E'xianling is not yet a designated protected area despite its unique geology and biodiversity. Logging and poaching was once uncontrolled and seriously threatened the wildlife and habitats of the area. Since 2009, Kadoorie Conservation China has been heavily involved in conservation management of E'xianling and different approaches have been used to conserve the unique ecosystem. A local ranger team was established and motivated to protect their own forest, local taxonomists were trained and local community outreach was conducted to raise awareness. The concept of citizen science was also adopted, and college students were recruited to assist in biodiversity surveys and community outreach. Lessons learned regarding protecting an unprotected area and some unresolved conservation issues will also be discussed.

Refilling empty forests: alleviating poaching pressure to recover wildlife in Southeast Asia

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Tropical countries are experiencing an unprecedented crisis of wildlife poaching that is driving numerous species to extinction, yet there is little scientific attention to human behaviour change for stemming poaching. This case study illustrates how to use social psychology principles to design community outreach programmes aimed at reducing poaching. We implemented this in a reserve in Thailand. The outreach activities aimed to build trust, raise awareness, provide motivation, offer simple opportunities for action, boost confidence to act, and generate social pressure against poaching—behaviour change is promoted when these conditions converge. From 2008–2011 we conducted 116 outreach events, focusing on farmers, schools, and local leaders. Poaching pressure dropped by 76%. Questionnaire surveys revealed 88% of villagers perceived a reduction in poaching, and the top reason given was the park outreach programme. In response to safer conditions, populations of five hunted mammal species increased throughout the park. Patrol effort was unrelated to the observed trends in either poaching or wildlife populations. The weight of evidence thus points to outreach as the main driver of a biologically significant decline in poaching that initiated the recovery of hunted species. This is one of the first demonstrations that scientifically designed and proactive park outreach activities might suppress poaching and initiate wildlife recovery in Southeast Asia.

How can we conserve banteng in eastern Cambodia? A case study in making decisions and developing a conservation strategy under uncertainty

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Over the past decade Cambodia's Eastern Plains Landscape has come to represent a last remaining stronghold

for banteng. Although significant numbers have been confirmed to persist in this landscape, populations are declining and the future of the species is by no means assured. The broad threats to banteng are not unique to this species, and include unsustainable hunting, habitat loss and degradation, and human disturbance. What remains unclear, however, are the precise mechanisms underlying these threats. For example; how many and which individuals are being hunted, and why? How might various types of disturbance affect mortality? The goal of conservation management within this landscape is to retain a viable population of banteng which can fulfil their full range of ecological functions. Rather than eradicate poaching entirely, a more feasible management objective is to ensure that the level of offtake remains below a certain threshold to allow the population to recover to somewhere close to carrying capacity. Determining what this level might be is complicated by the multiple sources of uncertainty associated with population size, structure and dynamics, and how these are impacted by various threats. One strategy to deal with this is to develop a number of realistic scenarios incorporating all of these factors across plausible ranges. These are used to set precautionary maximum tolerable levels of poaching, which are then adapted through an iterative process as more information becomes available. In describing how this approach might be implemented, we discuss minimum information requirements, and provide practical guidelines on acquiring relevant data. Such an approach has wide relevance for other species which, perhaps due to a perceived lack of charisma, are in danger of being overlooked by conservation efforts.

Studying fish passage in Khone Falls (Lao PDR) for a better connection between Mekong environmental hotspots

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The Mekong Basin is characterised by intensive long distance fish migrations, involving at least 103 species whose biomass reaches 800,000 tonnes per year. In 2010 the Mekong River Commission identified 32 environmental hotspots in the basin, including the Mekong mainstream between Vientiane and the Mun River confluence, the Mekong mainstream from Savannakhet to Khone Falls, and the Tonle Sap Lake system. The Khone Falls area in southern Laos constitutes, with its multiple channels and cascades, a major obstacle to fish migrations between Mekong mainstream environmental hotspots. We present a new project using the Khone Falls as a natural laboratory to assess the swimming capabilities, river morphology requirements and migration behaviour of dominant migratory fish species. This project combines direct observations, systematic gathering of local ecological knowledge, hydrological measurements and river geomorphological characterisation, and we detail here its approach and methodology. Field activities started in January 2015 and will last one year. The project will then produce a matrix detailing, for the dominant Mekong migratory species, flow conditions and river conditions passable, preferred or not passable. That information can be used to improve fish passage at Khone Falls to ameliorate the connectivity between Mekong environmental hotspots. It is also aimed at underpinning the design of more effective fish passes at dam sites in the Mekong Basin.

Targeted conservation to safeguard a biodiversity hotspot from climate and land-cover change

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Responses of biodiversity to changes in both land cover and climate change are recognised but still poorly understood. This poses significant challenges for spatial conservation planning because species could shift, contract, expand, or maintain their range inside or outside protected areas. We examined this problem in Borneo, a global biodiversity hotspot, using spatial prioritisation analyses that maximise species conservation under multiple environmental-change forecasts. We based this assessment on the extent of suitable habitat for 81 mammal species, and projected this information into potential future climates and land-covers, utilizing the findings of spatial deforestation model from 10 years of satellite data. Climate projections indicate that 11%–36% of Bornean

mammal species will lose $\geq 30\%$ of their habitat by 2080, and suitable ecological conditions will shift upslope for 23%–46%. Deforestation exacerbates this process, increasing the proportion of species facing comparable habitat loss to 30%–49%; a two-fold increase on historical trends. Accommodating these distributional changes will require conserving land outside existing protected areas, but this may be less than anticipated from models incorporating deforestation alone because some species will colonise high-elevation reserves. Our results demonstrate the increasing importance of upland reserves and that relatively small additions (16,000–28,000 km²) to the current conservation estate could provide substantial benefits to biodiversity facing changes to land cover and climate. On Borneo, much of this land is under forestry jurisdiction, warranting targeted conservation partnerships to safeguard biodiversity in an era of global change.

The role of GIS and remote sensing in conservation in Cambodia

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Protected areas in Cambodia and the region are under heavy pressure from industry due to an aggressive national development plan and high rates of economic growth. Likewise, social poverty and opportunism have resulted in unprecedented rates of land grabbing and agricultural expansion. Because of this need for land, most protected areas in Cambodia have been reduced in size by excising areas for urbanisation, settlement and agriculture, and converted for economic development purposes. Before these threats can be addressed, they must first be identified and monitored. WCS Cambodia uses geographic information systems (GIS) and remote sensing to monitor land-use changes in and around protected areas, map where the hotspots of land-use change are, analyse how they are being affected, and identify the priority places for preventative or reactive action. GIS and remote sensing techniques have detected areas that are under high threat from conversion and provided an early warning system for protected areas managers to undertake law enforcement against illegal developments and unplanned deforestation. This has also provided a clear visual demonstration of the impacts of these threats on Cambodia's protected areas to all stakeholders. GIS and remote sensing are extremely important tools for the conservation of the region's protected areas.

The SMART approach for tackling poaching, illegal trade and other forest crime: examples from developing Asia and Africa

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Arguably the most important tools to ensure the future survival of threatened species are well-managed protected areas. Parks are increasingly being seen as the best option to preserve viable wildlife populations in the face of rapidly increasing rates of hunting, unsustainable trade, and habitat loss. Unfortunately, many parks in tropical regions lack the necessary tools for effective management. Most currently lack systems to enforce staff accountability, assess threats, or evaluate success and failure. In response to the lack of capacity in parks, a broad partnership of conservation organisations has developed a set of tools collectively called the SMART approach. SMART (Spatial Monitoring and Reporting Tool) combines standardised patrol data collection, site-based database management and decision-making, and best practices for wildlife management. This approach empowers rangers, boosts motivation, increases efficiency, and promotes credible and transparent real-time monitoring of the effectiveness of anti-poaching efforts. Building on experience with existing law enforcement monitoring tools (e.g. Cybertracker, MIST), SMART provides park managers with the ability to quantitatively assess impacts, adjust strategies and enhance conservation success. Here we use examples from Asia and southern Africa to demonstrate how implementing the SMART approach has helped efforts to reduce poaching and illicit wildlife trade. Future efforts will seek to: (1) build essential capacity for SMART implementation and improved effectiveness of anti-poaching efforts; and (2) leverage SMART's position as a global platform to provide standardised measures of poaching levels and enforcement efforts for combating the poaching of tigers, elephants, rhinoceros and other endangered species.

The social determinants of bird hunting in Xishuangbanna, China and Luang Namtha, Laos

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Excessive hunting is a major threat to vertebrate species worldwide, particularly tropical birds and mammals. To limit hunting, a variety of policies have been proposed, but there has been inadequate evaluation of their efficacy and impact on wildlife populations. Northern Laos and Southwest China offer a unique opportunity to compare different hunting regulations, as well as the use of incentives (ecotourism revenue) versus punishments (fines, jail time, and the use of force) on changing local people's behaviour in a region with high ethnic diversity and biodiversity. Socio-cultural norms, economic conditions, perceived risk, and other factors may also influence the rate of hunting, which we investigate through household interviews. The project results will not only have implications for protected area and wildlife management in tropical East Asia, but will also have generalizable findings useful for conservation practitioners.

Role of topography in the distribution of island endemic trees in Hainan tropical rain forest, South China

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Habitat heterogeneity is a principal factor explaining species coexistence in plant communities, but its contribution to the distribution of narrow-range, endemic, tropical seed plant species is not clear. The study was conducted in a 20.4-ha forest permanent plot in Jianfengling National Nature Reserve, in the southwest of Hainan Island, China. The effects of topography on the distribution of 20 endemic species with more than 20 individuals were analysed. Species-habitat associations at different life stages were assessed by the Torus translation test. Effects of habitat heterogeneity on the spatial distribution patterns were evaluated by the complete spatial randomness model and heterogeneous Poisson Process model. The Torus translation test showed that occurrences of 75% of the endemic species were strongly associated with their habitats. Many species were positively or negatively associated with high slopes and ridges or valleys. RDA ordination analysis showed that all topographic attributes had significant influences on the distribution of the endemic species, but convexity was the highest, next to elevation and slope. Analysis of species spatial patterns showed that 80% of species had an aggregated pattern at small scales without heterogeneity effects. Aggregation effects declined and gradually shifted to regular or random patterns with increasing scale. Our results indicated that species endemic to Hainan have obvious habitat preferences, which supports the niche differentiation theory, and provide useful information for conserving endemic species in Hainan.

Assessment of wildlife species present in selected areas in northwestern Cambodia: a report from surveys in 2013 and 2014

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Between November 2013 and November 2014, the Angkor Centre for Conservation of Biodiversity (ACCB) conducted wildlife surveys in northwestern Cambodia to assess the presence of species of conservation concern and identify areas of conservation importance. Surveys were conducted in close collaboration with Cambodia's Forestry Administration within the Ministry of Agriculture, Forestry and Fisheries. Biodiversity assessment and survey efforts were concentrated in areas that had so far received little attention, and addressed gaps in our knowledge of the biodiversity in northwestern Cambodia. Thirteen areas, ranging from 542 to 17,889 hectares,

most of them protected community forest areas, were initially assessed using satellite imagery and forest user interviews to ascertain their potential conservation value and possible species present. Nine of these areas were surveyed using observational trail surveys, and four were surveyed using camera traps. Camera trapping efforts were focused on locations highly likely to support species of conservation concern, particularly at waterholes (*trapaeng* in Khmer language). The survey efforts detected 26 mammal species, of which 10 are listed as either near-threatened or threatened, including banteng *Bos javanicus*, gaur *B. gaurus*, pileated gibbon *Hylobates pileatus*, and Indochinese silvered langur *Trachypithecus germaini*. Six threatened bird species were detected, two of which are listed as Critically Endangered. Of particular note, the giant ibis *Thaumatibis gigantea* was identified well outside of the species' current published range. This study represents a contemporary assessment of the biodiversity of the study areas, a baseline for future assessment, and current information upon which to base land management recommendations and decisions.

Symposium—Monitoring rare or elusive species in challenging environments

Conservation under fire: the challenges of wildlife monitoring and data reporting in Karen State, Burma

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As Myanmar progresses with welcome political reform, this biodiversity hotspot offers the potential of bolstering the numbers endangered wildlife species and areas of pristine habitat in the region. However, with increased openness comes an inevitable loss of wildlife and habitats: either directly from targeted poaching or increased economic developments, or indirectly from increased access to, and population expansion in, once remote forest areas. The Myanmar Government now has the welcome support of many wildlife conservation organisations, particularly the Wildlife Conservation Society, WWF and Fauna & Flora International, working to aid them with assessments and protection of priority areas. However, some areas of Myanmar are not controlled by or therefore directly accessible to the Myanmar Government wildlife agencies or the conservation organisations. Karen State (Kayin State) is one such region, where much of the area is not government-controlled. Despite its high biodiversity, the occurrence and distribution of species in this region, while well-known locally, is not well documented in the available literature. Recent international conservation conferences, e.g. SCB 2014, and conservation action planning within Myanmar, e.g. MECAP, have not been able to account for the wildlife in this area and therefore these areas are less likely to be prioritised for protection from impending habitat and wildlife loss. How do we protect rare and elusive wildlife in a military conflict zone where much of the area is land-mined, where administrative hurdles from both conservation funders and the government slow progress, and where suspicion from local controlling factions lead to a reluctance to share wildlife abundance and distribution data?

Dhole *Cuon alpinus* (Pallas 1811) spatial occupancy in Baluran National Park, East Java

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Understanding the distribution of endangered species, especially at local scale, is crucial in conservation management. This study aimed to investigate the spatial occupancy of dholes *Cuon alpinus* (Pallas 1811), a poorly-studied Endangered species, in Baluran National Park, one of few remaining dhole refuges, located in the easternmost part of Java. A total of 181 dhole presence points were obtained from a field survey between March and July 2014. The presence data, along with 12 eco-geographical variables, were further analysed by applying an Ecological Niche Factor Analysis to: (1) investigate the relation between the environmental variables and dhole spatial occupancy (represented as marginality, specialisation, and tolerance indices); (2) map suitable dhole habitats. The

resulting overall marginality (0.861) and tolerance (0.612) indicated that dhole occupancy within the park was quite restricted. Dholes were more likely to occupy areas with lower altitude ('altitude' marginality coefficient = -0.53) in peripheral parts of the national park ('distance to border' marginality coefficient = -0.51). An important finding in the analysis is the dholes' tendency to approach villages inside or adjacent to the national park ('distance to village' marginality coefficient = -0.46), highlighting the emerging risk of conflict between locals and dholes. Without any precautionary measures, the situation may threaten dhole existence in the national park. Moreover, the produced suitability map showed that less than half of the total area was suitable for dhole occupancy (suitability index >40). Thus, maintaining habitat connectivity is vital to the preservation of dhole within the national park.

Conserving the Oriental pied hornbill *Anthracoceros albirostris* in Guangxi, China

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With the largest gape size among all forest birds of the region, hornbills are important for Asian rainforests. They are keystone species in tropical forest ecosystems and good indicators of forest health because they are among the few seed dispersers for large-fruited trees. Hornbills are also flagship species in conservation education for their charismatic shape and colouration, dependency on healthy forests, and unique breeding behaviour. The Oriental pied hornbill *Anthracoceros albirostris* is widespread and relatively common in the Indian Subcontinent and Southeast Asia. In China, this species was not uncommon in Southwest Guangxi and the southern parts of both Yunnan and Tibet, but due to habitat loss and hunting, it is now a State Protected Species and occurs in only a few fragments. Xidamingshan Nature Reserve (XNR) of Guangxi supports more than 50 birds, the largest hornbill population currently known in China. However, the forest in XNR was being encroached and poaching was pervasive. We have had an ongoing conservation project on this species since 2009. Various conservation actions have been carried out, including scientific studies, raising awareness and building the capacity of reserve staff. In 2014, we recorded and filmed the whole breeding process from incubation until fledging, which is the first complete field record for this species in China. This record provides important information on the diet and reproduction of this species, and shall further contribute to future conservation actions of the species.

Cryptic cats and elusive ungulates: multiple methods for monitoring large mammals in Laos

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We present a case study from the Nam-Et-Phou-Louey National Protected Area (NEPL-NPA) in Lao PDR, where monitoring activities have been conducted at a number of spatial scales to evaluate the effectiveness of interventions and to assess the status of key carnivore and ungulate species. The 6,000 km² NEPL-NPA is situated in the mountainous Northern Highlands and is recognised as one of the region's most important protected areas; best known for its mammals, especially carnivores. It harbours Indochina's last confirmed population of tigers and at least five other felid species. The primary pressures on mammal populations in this region are unsustainable hunting for consumption and trade. Population densities remain low and, combined with the extremely rugged terrain, impose difficulties for implementing monitoring activities. Since 2003, three different camera-trapping strategies have been adopted. In 2008 a sign-based occupancy survey was carried out across the entire NEPL-NPA. Hunting prevalence was also monitored through the use of patrol team records. The results of these monitoring actions were used as the basis for zonation within the NEPL-NPA, including the designation of a Totally Protected Zone. Furthermore, monitoring results were used to iteratively adapt both the law enforcement and community outreach strategies, and to determine the relative success of different elements of each strategy. Although monitoring indicates that the effectiveness of these strategies has increased, it remains uncertain whether they will be sufficient to conserve these populations in the long term, in the face of escalating threats and limited resources.

Current distribution, status and conservation challenges of the Asian water monitor *Varanus salvator* on Hainan Island

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The second largest lizard species in the world, the Asian water monitor *Varanus salvator*, is extremely widespread throughout southern and Southeast Asia. China represents its easternmost distribution in mainland Asia. Although still abundant in Southeast Asia, in China this species is now only found in several remnant pockets in the border regions of Yunnan Province and Hainan Island, while populations from Guangxi and Guangdong have been exterminated. The principal threats in China are hunting for meat and the destruction of its preferred lowland wetlands. Consequently, the species is listed as Class I nationally protected by China, and has been classified as Critically Endangered on the China Species Red List. Despite its high legal status and threatened status, the species is illegally traded in large numbers and wild individuals are poached whenever possible. The status of Asian water monitors on the tropical Hainan Island was little known, although records of wild-living animals of unknown provenance were occasionally reported in the last few years. Fortunately, a relatively healthy wild population was discovered in and around a nature reserve in 2012, which is protected by the local Li minority villagers due to local taboo. Together with the nature reserve staff, we are now collaborating with the local community for a joint effort to conserve the species with the following actions: (1) establish a monitoring team to conduct regular survey/patrol and stop any illegal poaching or habitat destruction; (2) study its ecology using radio-tracking; and (3) conduct education activities in the surrounding community to strengthen the villagers' conservation awareness.

Density, diet, and prey selection of the Indochinese leopard in eastern Cambodia

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Leopards *Panthera pardus*, the most persecuted large cats in the world, have been eradicated from >50% of their range in Asia. The Mondulhiri Protected Forest (MPF) in eastern Cambodia contains one of the last viable populations of Indochinese leopards *P. p. delacouri* in the region, as well as a high diversity of potential prey, including several threatened species. Recent increases in illegal logging and poaching are believed to be affecting the faunal community but little information has been gathered on this unique predator-prey community. Thus, the aims of this study were to determine: (1) current density; and (2) diet and prey selection of leopards in MPF. We conducted a camera-trapping study for leopards in 2014 in MPF and obtained density estimates using spatially explicit capture-recapture data, calculated using the program DENSITY. Results showed a density of 1.1 leopard/100 km², which was 70% lower than the leopard density estimated in 2009 in the same site. Analyses of scats (n = 83) revealed that leopards consumed at least 14 prey, ranging in size from insects and rodents to banteng *Bos javanicus*. In comparison to their availability, leopards selectively preyed most frequently on muntjacs *Muntiacus muntjak* followed by wild pigs *Sus scrofa*: both species were the most important prey animals in terms of total biomass consumed. We conclude that leopards are important apex predators in this unique ecosystem of eastern Cambodia. However, this important population of Indochinese leopards is declining at an alarming rate, and will soon be eradicated unless effective protection is provided.

Distribution and distance-based density estimation of langurs (*Trachypithecus* spp.) in Hin Nam No National Protected Area, Lao PDR

Oudone PHAKPHOTHONG

Both the black langur *Trachypithecus eburnus* and Hatinh langur *T. hatinhensis* occur within the karst-limestone-dominated habitat of Hin Nam No National Protected Area (HNN NPA) in central-eastern Laos. The Hatinh langur is classified by the IUCN Red list as Endangered, but the black langur remains unlisted. Very little is known about either of these species in terms of abundance, distribution or ranging behaviour, and uncertain-

ties remain concerning their taxonomy. This is largely a result of the species' highly restricted ranges and the challenge posed by undertaking any kind of surveys in this terrain. Hunting is believed to be the major threat to these langurs, particularly as HNN NPA is increasingly accessible to markets in Vietnam, but few data are available to demonstrate this. Ongoing rural development may also impact on these populations. This study represents the first attempt to rigorously estimate the distribution and density of these species in HNN NPA through the use of observation-based distance sampling. The analyses also attempted to investigate ecological processes such as habitat selection and the potential impact of threats. The results of this study will be used for strategic conservation planning, and monitoring and managing the species in the future.

Investigations of nest predation on ground nests in rock cavities in a limestone forest in southern China

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High nest predation is a common threat to birds in tropical regions, but few studies have looked at nest predation in limestone karst forests, particularly for ground-nesting birds that nest in rocky outcrops. We report on nest predation in the Nonggang National Nature Reserve, southern China, which is home to the common streaked wren-babbler *Napothera brevicaudata*, as well as the recently discovered and rare Nonggang babbler *Stachyris nonggangensis*. The Nonggang babbler nests in May, along with most other species, but the streaked wren-babbler is atypical in nesting in March. In March and May 2014, we placed three or four fresh Japanese quail *Coturnix japonica* eggs in natural rocky holes, representing artificial nests in the forest edge and the forest interior. A total of 182 nests (83 in March and 99 in May) were exposed for 12 days and checked every one, four or 12 days. Artificial rocky hole nests in May were subject to a higher rate of predation than nests in March ($\chi^2 = 41.78$; $P < 0.001$). Distance to the forest edge had no significant effect on predation, and nor did the characteristics of the hole itself. Shrub density near the hole was, however, related to predation in May. Our results suggest that nest predation strongly fluctuates seasonally in this limestone forest and may drive the seasonality of nesting for some species.

Estimation of core terrestrial habitat of the Hong Kong newt *Paramesotriton hongkongensis*

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To conserve and manage imperilled amphibian populations, a better understanding of their life history characteristics, such as habitat requirements and spatial use of habitat, is essential. The Hong Kong newt *Paramesotriton hongkongensis*—a species found only in Hong Kong and adjacent coastal areas in Guangdong Province—has been undergoing population declines, possibly due to habitat loss and overexploitation. Previous studies revealed that adult *P. hongkongensis* exhibit distinctive seasonal patterns in aquatic habitat use for breeding and make extensive use of terrestrial habitats during non-breeding season. However, knowledge of the terrestrial phase, which constitutes most of the life span of the Hong Kong newt, remains fragmentary at best. In this study, radiotelemetry and transect surveys were conducted to estimate home range sizes, core terrestrial habitat and characterise terrestrial habitat use. Radiotelemetry of terrestrial adults conducted during wet seasons indicated that *P. hongkongensis* utilise secondary forest habitat almost exclusively and maintain small home ranges (mean <0.2 ha). Core terrestrial habitats estimated for adult and subadult *P. hongkongensis* were 68.1 m and 92.1 m from the edges of streams, respectively. Results from this study demonstrated that secondary forests adjacent to streams are important habitats for *P. hongkongensis* during the non-breeding seasons, and the protection of this habitat (i.e. from illegal logging or forest fire) is an important parameter to be considered in conservation of this threatened species.

Fishes and food security in the Mekong River and its tributaries: a preview of life after the new dams are constructed

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The Mekong River ranks among the world's largest and biologically diverse rivers, and is of tremendous cultural and economic importance for the people of Southeast Asia. The river's biodiversity and fisheries are currently threatened by overexploitation and hydropower development. Knowledge of the Mekong fish and ecosystem ecology is extremely limited, and new research findings will be essential for management of anthropogenic impacts on biodiversity and ecosystem services. I investigated fish assemblages and the food web structure of the Mekong and its major tributaries in Cambodia. Stable isotope ratios of carbon and nitrogen from the tissues of fishes and other food web components were analysed to estimate the primary production sources supporting local stocks during the wet and dry seasons, and to examine the vertical trophic positions of fishes. Food web structure in all four rivers revealed major seasonal shifts. Seston and benthic algae were the most important production sources supporting fish biomass during the dry season, and riparian macrophytes appeared to be the most important production source during the wet season. Species that are largely restricted to floodplain habitats showed low seasonal variation in isotopic space. In the tributary river (Sesan) subjected to strong flow regulation, seston and benthic algae assumed even greater importance for supporting fishes. Relationships between body size and trophic position contradicted the popular concept of fishing down food webs, with heavily exploited fish stocks representing diverse trophic guilds. Fish diversity and fishery production in the Lower Mekong region are facing great threats with more dams being constructed.

Foraging habitat selection of the northern grey-rumped swiftlet *Aerodramus inexpectatus germani* in southern Thailand

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The white edible nest produced by the northern grey-rumped swiftlet *Aerodramus inexpectatus germani* is a popular traditional food in Southeast Asia. The volume of trade has been enormous and the demand is ever increasing. Nevertheless, little is known about the foraging habitat of this bird. We examined the intensity of foraging in five different habitats within their foraging range, and relate such intensity to insect availability. The foraging intensity was significantly different between habitats. The water-body edge has the highest foraging intensity with highest insect biomass and abundance. Furthermore, the birds also showed high foraging intensity over forest. Foraging intensity was significantly greater during the wet season than the dry season, which may relate to the intensive breeding period. These correlated to insect availability that varied over time and among habitat types. Populations of swiftlets are probably limited by the availability of insect prey. To conserve swiftlet populations, it is very important to protect both water bodies and forests within their foraging ranges.

Habitat determinants of bird communities in the selected key mine areas of Mindanao, Philippines: implications for conservation

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Mindanao Island is one of the centres of endemism in the Philippines whose biodiversity is at risk due to rapidly proliferating mining industries. However, bird communities and their response to habitat changes are scarcely studied. We examined the bird communities and habitat characteristics across various habitat types in the selected key mine areas in the northeastern, northwestern and southern parts of the island. The sampling sites in the northeastern and southern parts were mostly early secondary forests with some advanced secondary forest

patches while sites in the northwestern part were mostly agricultural areas and grassland. A total of 168 species of birds were encountered, of which 54 were Philippine-endemics, 15 were Mindanao-endemics and 21 were threatened. We used Canonical Correspondence Analysis to determine habitat gradients across the landscape and categorised the bird species according to their habitat associations. Threatened endemics were found to have narrow niches and were considered dependent on mature forests. Species distribution modelling predicted areas in Mindanao that potentially harbour viable population of bird species. It was revealed that areas with high habitat suitability for forest-dependent birds, and those with high congruence of bird species, are located mostly in the eastern parts (Caraga, Compostella Valley and Davao Oriental) where mining concessions overlap with mature forests. Our study implies the importance of mature forests on the island, indicating that proper conservation strategies for the forest-dependent, threatened endemics must focus on policy reform and proper coordination among concerned stakeholders towards regulating mining expansion.

Hierarchical spatial models of abundance using distance-sampling data: a methodological advance to evaluate conservation efficacy

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The need to rigorously evaluate management effectiveness in the conservation of tropical forests has never before been as acute as it is at present, when the global community is investing huge resources to arrest biodiversity decline. Yet, these evaluations are often restricted by methods that either focus on observation processes or on ecological processes of interest. However, the data used for such assessments is invariably generated through interaction between these two processes, obscuring the relationship between conservation targets (e.g. animal abundance) and management actions (e.g. habitat modification). We address this issue by developing hierarchical Bayesian models that explicitly incorporate both observation and biological covariates to understand the spatial patterns of animal abundance and their drivers. We demonstrate the application of this modelling approach through using distance sampling data from 77 line transects placed across 1,500 sq. km to examine the drivers of ungulate abundance in a highly productive forest landscape in the Western Ghats, India. These data were used to investigate the relative influence of biological and anthropogenic factors in shaping the abundance patterns of five threatened ungulate species, which differed in body size and diet. Based on the ungulate–habitat relationship established in this study, we predicted ungulate responses to varying management efforts. We then compared the relative contributions of different management actions in influencing the levels of ungulate abundance to help prioritise conservation interventions. Through this example, we illustrate the efficiency of the hierarchical modelling approach to build realistic models of species–habitat relations for robust evaluation of conservation effectiveness.

Long term density variation and the effect of landscape on great argus *Argusianus argus* in the rainforest of Southern Thailand

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The great argus *Argusianus argus*—a large bird in the family Phasianidae—is listed as Near Threatened. Currently this species is probably declining rapidly due to habitat loss and over-hunting. In Thailand, the density of the great argus was first estimated in 2001 using line transect distance sampling in the Hala-Bala Wildlife Sanctuary located on the Malaysian border. Our study investigated possible changes in argus density during the past 13 years and measured local landscape variables that could potentially affect their abundance. We also examined the micro-habitat of display sites used by males. We conducted surveys from March to August in 2014 during the breeding season when animals are easier to detect due to their increased call rates. We used listening posts that overlapped the line transects used during the 2001 surveys. The preliminary results indicated no decline and possibly an increase in density with 1.18 birds/ km² (0.83-1.68, 95% CI) in 2014 compared to 0.43 birds/ km² (0.32–0.57, 95% CI) for 2001. The abundance of great argus was also significantly positively related to distance from the sanctuary boundary. Male display sites (N = 33) were relatively open, having significantly fewer small-stemmed trees (≤ 3 m high and diameter breast height <10 cm) than the random plots (N = 62). Display sites also tended to be associated with termite mounds. Although these results are quite encouraging, indicating no decline and

possibly an increase in the population at Bala, overall ecological work on the species, as well as other threatened galliformes in southern Thailand, remains quite limited.

Impacts of extractive forest uses on bird assemblages vary with landscape context in lowland Nepal

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Forest use practices, such as logging, lopping off tree branches for fodder and grazing, do not reduce forest area but disturb forest structure and impact on biodiversity. Although such forest disturbances can be key determinants of the biota occupying a site, rarely is the interaction between disturbance intensity and landscape context considered, despite its relevance to conservation management. We investigated the influence of site- and landscape-level habitat characteristics on birds, and explored whether the effects of site-level disturbance on bird richness varied with forest extent in lowland landscapes in Nepal. While extractive uses reduced forest structural complexity and altered the avifaunal community of a site, the intensity of such effects depended on the extent of forest in the surrounding landscape (19.6 km²). The extent of forest, large tree density, and tree canopy cover were important predictors for all bird response groups. However, the effect of forest extent on bird richness was stronger for sites with greater disturbance intensity. Managing and restoring landscapes to support greater forest cover may not only have a positive direct effect on bird conservation, but may also help to compensate for site-level disturbances, which characterises multiple-use forests worldwide.

Overcoming the challenges of monitoring large waterbirds in a seasonally flooded forest, Prek Toal Core Area, Tonle Sap, Cambodia

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The Tonle Sap Great Lake in Cambodia is the largest freshwater lake in Southeast Asia. Its unique cultural, social and environmental values were recognised by its designation as a Biosphere Reserve by UNESCO in 1997. Prek Toal, the most important of three core areas, is the last significant breeding stronghold in mainland Southeast Asia for many globally threatened and near-threatened large waterbird species. The Prek Toal Conservation Project started in 2001 using local conservation teams, half of whom were former bird and eggs collectors, and half were government staff. The monitoring system began by setting up and testing different methods for collecting accurate information on the colonies. The dynamic hydrological system of the core area—which is flooded for six months of the year, with changing water levels and seasonally flooded forest—presents significant challenges for monitoring. Because different species of birds breed at different times of the year and the capacity of the data collectors was limited, some methods could not be applied and data collection had to be adjusted. The pilot monitoring system was not successful initially. After two years of testing and adjustment, however, we developed a method to undertake standardised colony population monitoring that provides quality information on each species from when they arrive to breed until they leave the colony. The project has been extremely successful, with harvesting reduced by up to 90% and we have recorded dramatic increases in the breeding populations of seven globally threatened and near-threatened species.

Multi-species, multi-agency monitoring for conservation: an example of best practice from the Eastern Plains of Cambodia

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The Eastern Plains Landscape (EPL) in Cambodia encompasses five connected protected areas and is one of the largest contiguous tracts of lowland forest in mainland Southeast Asia. WWF Cambodia and the Wildlife Conser-

vation Society (WCS) work within three of these protected areas, supporting the Forestry Administration and Ministry of Environment. The EPL contains a range of elevations, terrain and habitats, and these diverse resources support an exceptional array of wildlife species, including at least 18 Critically Endangered and Endangered mammals, birds and reptiles. Initial biodiversity surveys identified the species present, but increasing threats combined with a rapidly changing landscape continued to place increasing pressure on these threatened and elusive species, making it critical for the government to understand wildlife population trends to assist in implementing effective management strategies. WCS implemented line transect distance sampling in Seima Protection Forest in 2005, producing the first primate population estimates for the landscape. Continued collaboration and multi-agency networking resulted in line transect sampling being implemented in the two adjoining protected areas by WWF and government partners. This synergy has resulted in the longest-running and most reliable population monitoring programme for endangered primates and ungulates in Cambodia, revealing the world's largest populations of yellow-cheeked crested gibbon *Nomascus gabriellae*, black-shanked douc *Pygathrix nigripes*, and banteng *Bos javanicus*; further highlighting the importance of this landscape for conservation. The continuation of joint multi-agency collaboration using robust protocols to monitor priority species is crucial in monitoring the effectiveness of current conservation strategies and applying adaptive approaches when necessary.

Predicting the distribution of green peafowl *Pavo muticus* in Java, Indonesia using a species distribution model

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The green peafowl *Pavo muticus* is categorised as an Endangered species on the *IUCN Red List of Threatened Species*. It faces a diverse range of threats including widespread hunting, coupled with the degradation and loss of its open forest and woodland habitat. Java is the only island in Indonesia where the bird occurs. However, knowledge of the bird's distribution across the island is limited. This present study assessed the potential current distribution of the species using a species distribution model, MaxEnt. A dataset of bioclimatic variables (precipitation and temperature), altitude data, and a vegetation index were used as model inputs along with presence-only data from four sites across Java. Modelling showed that annual precipitation, April Normalized Difference Vegetation Index (NDVI), altitude, and temperature seasonality variables appeared to be the most important variables contributing to the final potential distribution prediction. The predicted suitable habitat map has shown a good match with historical and present records of green peafowl, and succeeded in capturing a wide range of habitat patches from tiny spots to quite large areas of suitable habitat. In addition, this study predicted several new potential suitable habitat areas, apart from its former historical and recent distribution. However, a fairly large amount of potential suitable habitat is found outside of existing conservation area. Conservation efforts are urgently required, especially within the distribution range outside protected areas.

Shifts in rainforest mammal communities from fragments to edges to interior forest

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Extensive deforestation throughout the tropics has left most persisting forest in isolated patches, surrounded by agricultural lands that are inhospitable to many forest species. Small forest fragments support a small fraction of forest-dwelling species, but even large forest areas can suffer great biodiversity losses along habitat edges. We quantified these losses through camera trap surveys conducted in and around Chiew Larn Reservoir, Thailand. We placed cameras on islands in the reservoir and in the mainland forest surrounding the reservoir, along transects from the reservoir edge into the interior forest. We have measured what fraction of biodiversity is lost and which species survive—in forest fragments and edges—and then summarised any particular characteristics shared by the survivors. As deforestation rates continue to rise in the tropics, our findings will help us to predict how biotic communities will respond to ongoing fragmentation.

The flexibility of distance sampling data for monitoring rare species—an evaluation of density surface models versus conventional distance sampling

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Distance sampling is a suite of methods that have become some of the most widely used techniques for estimating the abundance of biological populations. One of the fundamental requirements, however, is an appropriate number of observations of the objects, or groups of objects, of interest with which to conduct the analysis. This often deters researchers from using these methods for rare or elusive species. Advanced distance sampling techniques have been developed that may prove useful to researchers faced with challenging environments or species that do not conform to standard distance sampling assumptions. We present the results of a long-term wildlife monitoring programme from Seima Protection Forest in eastern Cambodia, conducted by the Wildlife Conservation Society in collaboration with the Forestry Administration, Royal Government of Cambodia, over the last 10 years. We will evaluate the use of both conventional distance sampling and density surface modelling for estimating the abundance of rare species. We demonstrate that in some instances conventional distance sampling can be effective for monitoring elusive species, but we will highlight the difficulties associated with this approach. We will then evaluate the use of Density Surface Models as an alternative, and present the benefits and challenges of estimating abundance using environmental covariates within a model-based framework. The fundamental differences between design-based and model-based inference in the context of rare wildlife species, challenging environments, and low technical capacity will be discussed.

Wildlife detection dogs: lessons learned and future potential in tropical Asia

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Due to their extremely powerful sense of smell, trained wildlife detection dogs can greatly increase the efficiency of field surveys in a range of contexts. Dogs can search large areas and difficult terrain more easily than human search teams and detect targets (i.e. animals or animal signs) that human observers may miss, thereby potentially alleviating sources of bias. Detection dogs can be used to rapidly and reliably establish species presence in certain scenarios and increase detection rates and therefore sample sizes. However, training and handling of such dogs is a specialised skill and the logistical and financial costs associated with deploying canine survey teams can be high compared to, for example, employing local field assistants. Nevertheless, there is ongoing interest in this method, and it is particularly appealing where rare and cryptic species are concerned and where acquiring an adequate sample size continues to be a challenge. We first present several short case studies from Southeast Asia where detection dogs have been used in a limited way and with mixed success in terms of results. We then contrast this with a number of studies from other areas that demonstrate just how effective dogs can be in the right circumstances. We use these examples to formulate some general guidelines on when the use of detection dogs might be warranted and key factors that must be taken into account when considering this approach.

A status report on giant ibis *Thaumatibis gigantea* nesting in the Northern Plains of Cambodia: a direct payments for conservation programme and fledgling success results from 2005 to 2014

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In 2005 the giant ibis was designated by Royal Decree as the national bird of Cambodia. The deciduous dipterocarp forests of the northern plains landscape support a globally significant population of this Critically Endangered species. To strengthen and encourage local conservation, the Bird Nest Protection Program was initiated in 2002 by government partners, with financial support from Wildlife Conservation Society (WCS), to locate, monitor and protect nesting sites. Under the programme, local people and contracted community rangers locate nests within both Kulen Promtep Wildlife Sanctuary and Preah Vihear Protected Forest.

Symposium—Moving beyond integrated conservation and development: making incentives work for conservation

Communities can manage conservation incentive schemes

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The subsistence community in Tmatboey Village, Kulen Promtep Wildlife Sanctuary, Cambodia, once hunted the Critically Endangered giant ibis *Pseudibis gigantea* and white-shouldered ibis *P. davisoni*. With a global population of fewer than 500 breeding adults for both birds, the Wildlife Conservation Society (WCS) had to find an innovative and effective scheme with community 'buy in' to conserve these species. To protect habitat and ensure tenure security for residential and agricultural land, the village worked with the WCS and authorities to map their land and resource use. A Community Protected Area (CPA) was established, along with a committee to regulate resource use from the CPA. Awareness-raising activities were initiated and the village signed a conservation agreement not to hunt key species of wildlife, allowing WCS to initiate the development of ecotourism activities in 2003. The Sam Veasna Center for Conservation (SVC) was established by WCS to develop and manage wildlife tourism at WCS sites and build the capacity of local communities in the provision of tourism services. In 2006, the committee took over management of ecotourism. Since then, the committee has regulated land and resource use, successfully protecting the ibises and earning about 20,000 USD per year for the village, with ongoing support from WCS and SVC. This extremely successful model is now being replicated in other sites throughout Cambodia. We discuss the lessons learned from Tmatboey relevant to other similar community-based conservation incentive schemes in the region.

Conservation incentive schemes: predicting conditions for success

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The use of incentive schemes in conservation is growing rapidly, yet there is still significant debate regarding the conditions required for success. This is due in part to the importance of tailoring incentive-based interventions to the local context. To do this well requires an understanding of how responses to incentives are likely to be influenced by the local institutional conditions and behavioural norms, which can be difficult to predict without prior investigation. Conversely, implementing incentive schemes without a prior understanding of the local context risks undermining the process from the beginning. In this talk, I will present evidence from a series of behavioural economics approaches used to investigate the responses of small scale Cambodian resource users to different incentive schemes to show how predictive empirical approaches can be used to identify the conditions for successful implementation of conservation incentive schemes.

Dai Holy Hills: sanctuaries of biodiversity in Xishuangbanna, Southwest China

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Sacred forests protected by indigenous peoples are receiving increasing attention for their promise in squaring conservation goals with social benefits for local communities. However, conservation projects often assume indigenous cultures are static when in reality these are evolving systems. Thus, dynamic understandings of sacred forests are critical for implementing equitable community-based conservation. The Holy Hills, sacred forests protected by indigenous Dai people, have generated great interest for conservation in Xishuangbanna—a region containing the world's northernmost tropical rainforest and China's richest biodiversity. Xishuangbanna's rainforests are rapidly being replaced rubber plantations, with more than 1,400 km² converted since 1976. The Holy Hills are virtually the only remaining forest patches outside government nature reserves, and they have been documented to contain rare species and ecosystems underrepresented in protected areas. Moreover, the

Holy Hills embody conflicting local interests: maintaining sacred forests for appeasing ancestral spirits is understood in Dai culture as necessary for community wellbeing, but converting Holy Hills for rubber production can improve material security and social standing in Chinese society. I investigate cultural changes affecting Dai–nature relationships since the advent of rubber cultivation and conservation concerns, the implications such changes have for competing interests over maintaining the Holy Hills, and how these dynamics influence land use practices with environmental consequences. Ultimately, I seek to understand when and how community goals for protecting sacred forests are compatible with conservation goals. This is important for engaging science and policy-making in a way that both conserves biodiversity and supports cultural self-determination, a struggle in conservation projects worldwide.

Diving as an incentive-based conservation mechanism: what have we learned in Thailand in the last 20 years?

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Diving can provide an incentive-based mechanism to achieve marine conservation goals. We have been conducting research on this topic for over 20 years in Thailand, especially on coral reefs, to examine the management approaches that may lead to more effective use of diving. This paper reports on several studies, including use of a Limits of Acceptable Change approach to visitor management at Koh Chang, and the implications for conservation of the changing nature of the dive industry and its clientele based on a comparison of Phuket diver survey data from 2000 and 2012. The industry is becoming increasingly dominated by low-paying generalist divers with low economic returns, modest diving skills that have greater potential to negatively affect reef conditions, and with lower interests in reef ecology. More than a third of divers interviewed would not return to dive if the reefs were bleached from global climate change. There was also significantly reduced interest in participating in reef conservation activities, such as restoration and monitoring, in 2012 compared with the earlier survey. The studies suggest that diving is becoming a less effective tool for conservation in the future in Thailand due to increased impacts, lower economic returns, the impacts of global change and changing clientele.

Forest Impact Venture: linking conservation goals and business in sustainable manner

Amalia MALING and Sybille BORNER

WWF Cambodia

The Eastern Plains Landscape (EPL) is one of the largest (10,000 km²) networks of protected areas in Cambodia and home to Critically Endangered species and around 40,000 indigenous Phnong communities who rely on forest resources for their livelihoods, contributing around 50–80% of their income. WWF has piloted in Cambodia the Impact Ventures@WWF project that links conservation goals and business in a sustainable manner. This is rooted in an earlier project that piloted conservation agreements with two communities in Monduliri Province and developed sustainable non-timber forest products (NTFP) management processes. Funds from the conservation agreements were used to pay forest patrols and scale up enterprises. It became clear from this project that the enterprises, if organised as an association, had the potential to contribute significantly to forest conservation. At this stage of the project, a community venture of sustainably harvested NTFPs has been established which processes, brands, and sells the products, adding value to create funds for forest conservation. This can potentially generate annual revenues of \$50,000 and provide increased incomes to 500 honey, resin and bamboo collectors. The presence of a legal framework allowing tenure to community forests, willingness of community members to patrol, and a competitive compensation for patrolling, are key factors to the success of this project, as well as teaching management skills to ensure the commercial success of the venture.

Land tenure and livelihoods in Indonesia: a case study of land conflict in Rempek Village, Lombok

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Land tenure in Indonesia is a complex combination of traditional, formal and informal arrangements. Historical developments and legal ambiguity over land and natural resources has resulted in widespread tenure insecurity, impacting on livelihoods and conservation initiatives. This is reflected in the case study of Rempek Village, Nusa Tenggara Barat, where conflict over land tenure and forest boundaries has occurred since 1984. A timeline of these events was built using discussions with a number of stakeholders, including people living inside the conflict area, people from Rempek Village, the village head, NGOs, the local forest management unit and National Land Agency staff. Dates, letters and legal documents outlining historical events were obtained to support these discussions. It was found that the major driver of this conflict was disagreement over the forest boundaries between the Ministry of Forestry and the National Land Agency. This escalated into a vertical and horizontal conflict, negatively affecting livelihoods in the area. The land conflict in the forest area of Rempek Village exemplifies widespread issues in land tenure in contemporary Indonesia. All over the country, agrarian conflict and tenure insecurity have stimulated political movements. Security of tenure has a direct relation to the success of conservation initiatives, including incentives for maintaining forest areas and minimising large scale deforestation. Because land is a key resource in Indonesia, stronger coordination between land authorities is required, as well as a comprehensive understanding of the complex social, economic, and political aspects of land tenure.

Monitoring the effectiveness of community conservation areas in the Eastern Plains Landscape, Cambodia

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It is recognised that forests managed by local communities for sustainable use of goods and services can be effective in biodiversity conservation. Thus, one of WWF's strategies in Cambodia is to support Community Forest (CF) and Community Protected Areas (CPA) in Mondulhiri Protected Forest (MPF) and Phnom Prich Wildlife Sanctuary (PPWS) in the Eastern Plains Landscape (EPL). Within this context, WWF is supporting the development of a business model based on non-timber forest products that could ensure long-term payments for community conservation areas. To assess the effectiveness of the model, WWF is piloting different tools for monitoring conservation threats and biodiversity state. Since 2014, WWF Cambodia has piloted SMART (Spatial Monitoring and Reporting Tool) in two community conservation areas: Trapeang Khaerm CF and Khneng CPA. SMART is a law enforcement monitoring software developed by several conservation NGOs including WWF. SMART has been implemented in the EPL by WWF since 2013, in partnership with the Ministry of the Environment in PPWS, and with the Ministry of Agriculture, Fisheries and Forests' Forestry Administration in MPF. SMART is a tool to increase the performance of law enforcement rangers in biodiversity protection. Piloting SMART in the two communities will: (1) provide information about the status of the threats in the conservation areas; and (2) contribute to information on law enforcement operations in MPF and PPWS. Additionally, biodiversity is being monitored through forest cover change and 10 transects per site. Based on the pilot experience, a comprehensive monitoring system will be developed.

Paradise lost? The status and future of East Rennell World Heritage Area, Solomon Islands

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I will document threats and conservation actions needed for East Rennell World Heritage Area (WHA), an imperilled site in the Solomon Islands. The site is part of Rennell Island, the largest raised coral atoll in the world. In 1998, East Rennell WHA was considered to have a high degree of 'ecological integrity', but there are now many

threats to the area, including logging and associated invasive species. Consequently, in June 2013, the World Heritage Committee adopted a decision to place it on the 'List of World Heritage in Danger'. Further threats include climate change and increased salinity of its freshwater supplies. Successful protection and management of East Rennell WHA is contingent on 'buy in' from the local people who own the land under customary laws. It would seem that the local people lack capacity to manage the property under the current arrangements. These effects are compounded by their isolation and a severe lack of funding, resources and World Heritage training.

Potentials of participatory resource management approaches: a case study of the Cox's Bazar participatory forestry programme, Bangladesh

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In participatory forestry (PF) projects in Bangladesh, fast growing exotic species have been mostly planted with some native species so that participants can receive greater returns after the final harvest. We measured trees in sample plots within a forest and calculated an Importance Value Index (IVI) to determine the distribution of species in the plantation forest. *Acacia auriculiformis* was the most important species with the highest IVI (171). The presence of an *Acacia* hybrid was about two times lower (IVI 76) than *A. auriculiformis*, while *A. mangium* (IVI 43) was given the lowest priority of the exotic species. Conversely, native species had the lowest average IVI (10) across all of the species. We also interviewed participants and found that PF accelerated diversification of income sources of households. Moreover, after the final harvest, on average each participant would receive approximately US\$ 1,509/ha. In addition, social bonding, sense of security and women empowerment were improved after PF implementation. However, mistrust between Forest Department and local people was apparent. Inequity was also observed in distributing PF plantations among participants. The regression model generated in this research will help to determine the equal plot size for each participant and thereby enhance social equity. This research will contribute to improving PF management and enhancing species diversity in Bangladesh.

Rice protects Critically Endangered birds

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Inspiring subsistence communities to protect wildlife is a challenge. The Ibis Rice project is a payments for ecosystem service scheme in Cambodia that tries to do this. Initiated in 2007, it targets communities located inside protected areas with many endangered species, such as giant ibis, white-shouldered ibis, Eld's deer and Asian elephant. The communities depend on the forest and surrounding areas for their livelihoods, which overlap with important wildlife habitat. The Ibis Rice project builds on land use plans developed by the community and the relevant government institutions with the help of WCS, as part of the zoning process clarifying resource tenure and management responsibilities. Through an elected Village Marketing Network (VMN), the Ibis Rice project pays a premium price for rice to farmers who abide by land use plan rules and regulations. Implementing the project requires providing the correct forums, incentives and procedures for attitude and behavioural changes to occur. I will highlight the specific steps undertaken by the VMN and community to transparently monitor compliance and complete the buying process. Over the years, the process has moved from being supervised by WCS and the VMN to being monitored by the communities themselves, and the project has grown from four to 18 villages. Since 2013, the communities have involved their commune councils, thereby institutionalizing the process. Villagers now accept that the process is not biased and there are no conflicts regarding decisions. There is the beginning of ownership and compliance, and we hope it will become stronger with time.

Best practices in development of the Environment Impact Assessment law in Cambodia

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To improve economic development, many countries around the world have heavily exploited natural resources,

resulting in serious environmental impacts. Environmental concerns have become a very important global issue to discuss and find solutions for sustainable development. In Cambodia, drafting of the new Environmental Impact Assessment (EIA) law for the Ministry of Environment (MoE) started in 2011. The purpose of this work is to update the law in line with the pace of the country's economic development and current issues, including climate change concerns, trans-boundary EIA, strategic environmental assessment and public participation processes, as well as to improve the enforcement of EIA regulations, build staff capacity, upgrade the EIA department and establish an environmental fund. The key processes for developing the draft EIA law have included getting public involvement in the EIA law development process, creating a new EIA law with good applicability and creating stakeholder 'ownership' of the law, especially the private sector and the communities who are or will be affected. This EIA law could become a very important legal instrument to help encourage best practice EIAs in Cambodia, and help the MoE achieve its mission of the environmental protection, biodiversity conservation, and effective use of natural resources. The process followed in Cambodia could serve as a best practice example for other countries in the region.

Biodiversity in Hon Ba Nature Reserve, Khanh Hoa, central Vietnam and its threats

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The eastern biogeographical region of Vietnam, especially the Annamite chain, has several hotspots of floral and faunal diversity. New scientific methods and concepts, and the systematic exploration of favourable environments—particularly the mountains—has led to the discovery of many new taxa and to a more detailed analysis of the biogeographic relationships in the eastern region. The Hon Ba Nature Reserve is where the Annamite chain meets the East Sea, next to the Lang Biang Plateau. It is a habitat with high endemism. The reserve lies from 20–1,545 m above sea level, supporting a diversity of landscapes and habitats. Only about 700 plant species had been reported by 2010, because there had been few systematic studies prior to 2013–2014, when two surveys were undertaken on the flora and fauna. These studies revealed a total of >1,400 plant species, many of them are endemic to Vietnam, and many being new records. There was also a confirmation of a thriving population of the orchid *Paphiopedilum delenatii*, a Critically Endangered species that had recently been considered extinct in the wild. About 300 species of animals were recorded. Hon Ba Nature Reserve is facing threats from human impacts: deforestation for illegal mining, and mass-collection of non-timber forest products and precious wood.

Symposium—Local and global challenges to conserving threatened tropical marine mammals in Asia

Conservation status of cetaceans in Kien Giang Biosphere Reserve, Kien Giang Province, Vietnam

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We conducted the first systematic studies of cetaceans in Kien Giang Biosphere Reserve (BR). We completed 22 parallel line transects with total length of 501 km. A total of 1,964 km² was surveyed between the Rach Gia and Ha Tien ports along the coast of Kien Giang BR. During this survey, we had only four on-effort sightings of a total of 19 Irrawaddy dolphins *Orcaella brevirostris* and two on-effort sightings of two finless porpoises *Neophocaena phocaenoides*. The encounter rate was 6.9 Irrawaddy dolphins and 0.4 finless porpoises per 100 km. The first photographic database for Irrawaddy dolphins in Kien Giang BR has been established from this study. A catalogue compiled from three opportunistic surveys in 2011, 2012 and 2013 included 42 recognisable individuals. Mark-recapture analysis suggests there are 153 Irrawaddy dolphins (CV = 0.39) in the survey area. This estimate is still being debated because of differences between systematic and opportunistic surveys. Eight whale temples, nine

cetacean shrines and three cetacean graves containing a large amount of skeletal material have been located in Kien Giang BR. Indo-Pacific bottlenose dolphins *Tursiops aduncus* and pygmy sperm whales *Kogia breviceps* were added to the Kien Giang BR species inventory from the whale temple data. Semi-structured interviews were undertaken with 33 local fishermen. Our data show a high intensity of fishing activity using a wide range of equipment in Kien Giang BR. Bottom trawling, which has been identified as a destructive fishing method, is still popular among local communities.

Conservation status of Irrawaddy dolphins in the Peam Krasop Wildlife Sanctuary, Cambodia

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The Peam Krasop Wildlife Sanctuary (PKWS) is among the most significant protected areas in Cambodia and most significant mangrove forests in Southeast Asia. An intensive four-day training course was held for a team of 12 local researchers on dolphin assessment techniques followed by surveys of these waters during 10 days in October and November 2013 and seven days in February 2014. Irrawaddy dolphins were found most frequently just offshore from the Prek Bak Khlong, Old Peam Krasop, and Lam Dam channel mouths as well as along the Northwest coast of Koh Kong Island in waters affected by freshwater outflow from the Trapeang Rong and Tatai Rivers. Although the overall number of Irrawaddy dolphin sightings was low, group sizes were high, ranging up to 19 individuals. Group sizes were almost double, and sightings much more frequent, while following opportunistic versus systematic transect lines, probably because the former took the survey team through the main channels linking inland waters and open seas, which are the preferred habitat of the species. The clumped distribution of the dolphins in the mouths of channels leading in and out of the mangrove forest offers key opportunities for conservation management in terms of taking a zoning approach to fisheries that threaten the dolphins (e.g. gill nets and possibly trawl fisheries) due to accidental entanglements and for developing well-managed ecotourism focused on watching dolphins.

Detecting the unseen through application of a robust mark–resight design for estimating humpback dolphin demographics in Bangladesh

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Estimating the demographic parameters of highly mobile wildlife is particularly challenging when detection is imperfect and only an unknown portion of the geographical range of a super-population can be sampled. Addressing this challenge has vital implications for protecting species whose distribution and conservation risk are poorly known. A mark–resight analysis under a robust design was applied to Indo-Pacific humpback dolphins *Sousa chinensis*, in open estuarine waters offshore of the Sundarbans mangrove forest, Bangladesh. During three winter seasons in 2010–2013, 88 humpback dolphin sightings were made along more than 5,000 km of track line. Almost 43,000 dorsal fin photographs resulted in the identification of 468 individuals, with an average re-sighting rate of 0.85, and abundance estimates of 132, 131 and 635 for the three winter seasons, respectively. The considerable increase in the abundance estimate during the third season can be explained by the large number of new dolphins identified for the first time during the third year. This includes a single group of 205 photo-identified individuals that is by far the largest group ever recorded of the species. The increase is also reflected in a 55% probability estimated using a robust design over the three winter seasons of an individual remaining in an unobservable state in the next survey when in an unobservable state in the previous survey. The results of this study indicate that the coastal waters in our survey area support a portion of a larger super-population that occupies a more extensive area in both Bangladesh and India.

Population estimate of Irrawaddy dolphins *Orcaella brevirostris* using mark-recapture method in Trat Bay, Trat Province

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Trat Bay is an important fishing area for communities along the Eastern coast of the Gulf of Thailand as well as the habitat of the Irrawaddy dolphin *Orcaella brevirostris*, a threatened species in Thailand. The distribution of Irrawaddy dolphins in Trat Bay was investigated between 2010–2012 using standard line transect surveys. Every dolphin was identified by means of photographic identification techniques in which the characteristics of the dorsal fin and wounds of each dolphin were studied and recorded. The survey data were analysed with mark-recapture software. According to our results, the estimated population of Irrawaddy dolphins in Trat Bay is between 81–199 individuals with an average over the three years of 117 ± 28.5 individuals within a 95% confidence interval. The photo-identification method helped to avoid double-counts during field surveys and revealed new animals recruited every year. The mark-recapture analysis evaluated changes in group sizes from births, deaths, immigration and emigration. Finally, this study indicated that the Irrawaddy dolphins that inhabit and forage in Trat Bay undergo seasonal migrations to follow their prey. Therefore, the population size of dolphins in Trat Bay may change continually due to temporary immigration and emigration from nearby populations. Data from this study can serve as a baseline for the management of Irrawaddy dolphins, which is especially needed during their mating and calving seasons.

Study of Bryde's whale in the upper Gulf of Thailand

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Bryde's whale *Balaenoptera edeni* is a baleen whale that uses baleen plates to filter fish from seawater when feeding. The main food of Bryde's whale is anchovies. In the upper Gulf of Thailand, Bryde's whales are distributed along the coastlines of Phetchaburi, Samut Songkram, Samut Sakhon, Bangkok, Samut Prakan and Chon Buri provinces. This study was conducted during January 2010–December 2014 using photographic identification methods. The method identified Bryde's whales from the distinguishing characteristics of their dorsal fins and from wounds and marks on their bodies and flukes. The colour patterns at the upper jaws and in the mouth were also observed. A population of 48 Bryde's whales was identified, including 12 females with a total of 19 calves. The mother and calf pairs stayed together for at least 17 months. Bryde's whales were mostly found between April and November. The coastlines in the upper Gulf of Thailand play an important role as feeding, breeding and nursing grounds for Bryde's whales.

How do you know it's not there? Searching for rare marine species

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Searching for rare marine species is hard. As researchers, how can we be confident that zeros represent the true absence of a marine species? Our research provides guidance for sampling some of the hardest marine fish to find — those that are small, data-poor and cryptic. We used our experience searching for seahorses in Thailand over two research seasons to evaluate how well transects and timed swims worked at finding these cryptic marine fish. In addition, we simulated two survey design strategies to evaluate cost-effectiveness and conducted a sensitivity analysis of the effort (number of sites to visit and repetitions per site) required to have confidence that any zeros represented the true absence of the species of interest. Our results highlighted that timed swims found seahorses in a shorter time and in fewer surveys than transects, despite little difference in their comparative ability to find seahorses. In terms of future survey design, our simulations show that five replicates of either transects or

timed swims provide a 90% confidence level in knowing if a small, cryptic marine fish is present or absent for a standard survey design. However, to visit as many sites as possible, given limited time and funding, a removal survey design—whereby surveying stops once the species is found or until a pre-determined number of replicates is completed—is recommended. Incorporating the detection ability of underwater search methods is critical to answering basic questions of where and how to find your small, data-poor marine species.

SPECIES AND ENVIRONMENT

Symposium—Fig trees and associated animals

Geographical variation in the pollination of an Asian fig tree

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Figs are eaten by a greater range of animals than the fruits of any other trees, from ants to elephants, but they are also of evolutionary interest because of their intimate relationship with pollinator fig wasps (Agaonidae, Agaoninae). Very few plants have active pollination, whereby insects deliberately collect pollen from anthers and deposit it on stigmas. Some fig wasps are active pollinators, others are passive, and transitions between the two states have occurred several times. Actively pollinated trees benefit from needing to produce much less pollen, and active pollinators often benefit from developing in pollinated ovules. Floral (male : female flower) ratios in figs are usually a good predictor of pollination methods. Here we describe a situation that should throw light on the selection pressures acting on pollination behaviour and floral ratios. *Ficus tikoua* is a low-growing Chinese dioecious fig tree that produces figs on the ground. Floral ratios in its figs cover the range expected for both passive and actively pollinated species, with clearly defined regional variation in putative pollination methods. Related fig trees are all actively pollinated, and we may be observing a transition to passive pollination driven by routine pollen limitation.

How do non-pollinators locate *Ficus* hosts?

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The highly obligate pollination mutualism between figs and their fig wasps (Agaonidae, Chalcidoidea) is usually exploited by non-pollinating wasps. These occupy female flowers to oviposit and could negatively impact fig-wasp mutualism. Pollinators select species-specific *Ficus* hosts by the characteristic bouquet released from receptive figs. However, as non-pollinating fig wasps lay eggs in the same day, how do they locate appropriate figs? Dioecious *Ficus hispida* is pollinated by *Ceratosolen solmsi marchali*, and a non-pollinating fig wasp *Philotrypisis pilosa* lays eggs with a long ovipositor outside of the figs once the pollinator has entered the receptive fig. In this study, we performed behavioural choice experiments on *P. pilosa* with a Y-tube olfactometer and then researched electrophysiological responses using GC-EAD. The results showed that *P. pilosa* visited the figs for seven days from the near-receptive phase to after pollination. 65.80% of *P. pilosa* visited the figs after the pollinator's arrival. However, 84.53% of *P. pilosa* laid eggs once the pollinators had entered the figs and the species was significantly attracted both by the receptive figs and pollinators when its choices between receptive figs vs. air and n-hexane extract of pollinators were tested. Electrophysiological recordings showed that the species responded to compound linalool released from receptive figs, and the compounds docosane and tricosane from an extract of pollinators. These results reveal that non-pollinating fig wasps are not only attracted by volatiles from host trees but also from the pollinators. This may be due to the food requirements of non-pollinating fig wasps.

Offspring production decreases due to chemical deterrence by mother pollinating fig wasps

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How can cooperation be maintained when interacting partners conflict over their shared and limited resources? The nursery pollination mutualism of figs and fig wasps provides a model to explore how the cooperating partners avoid a “tragedy of the commons” in the evolution of cooperation. Our recent work has shown that an interference competition effect arises between fig pollinators when they decrease the number of eggs they can potentially lay. By doing so, the pollinators limit the use of the common resource provided by the fig flowers. We designed experiments to investigate whether chemicals are involved in this oviposition decrease. Ten compounds of fig volatiles and 12 compounds of fig wasp extracts that were absent before pollination appeared after pollination. Among these 22 compounds, only four fig wasp compounds had been previously accounted for in the literature as belonging to the oviposition deterrence pheromone (ODP) family. Of these four compounds, linolenic acid had already been accounted as an ODP for the wasp’s closely related species of honeybee. Because amongst the four compounds, linolenic acid was found at relatively higher concentrations, we manipulated its concentrations in a subsequent experiment. By artificially increasing linolenic acid concentrations within the fig fruits, we found evidence for its ODP effect. The wasps therefore seem able to preserve an unsaturated common resource by releasing linolenic acid, hence stabilizing cooperation.

Niche differentiation in the ant community on the dioecious fig tree *Ficus benguetensis*

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Little is known about how reproductive and ecological differences between male and female fig trees affect ant communities. This study aimed to identify and investigate the influence of these differences on an ant community foraging on the dioecious fig tree *Ficus benguetensis*. The fruiting phenology of 25 trees located in northern Taiwan was surveyed weekly for one year. The number of syconia and their developmental stages on a given area of the trunk were counted and recorded. The simultaneous occurrence of fig wasps, ants and the type of ant nests was also recorded. The abundance and synchronisation of syconia were significantly greater on male fig trees than on female trees, as were the abundance and species diversity of ants. In addition, the activity of abundant ant species was correlated with specific developmental stages of the syconium. Our data suggest that variations in the resources provided by syconia (which can provide various wasp prey at different syconium stages, e.g. pollinator wasps, parasitic wasps and aphids) lead to significantly different ant communities on the two sexes of *F. benguetensis*. In addition, we found that the contingency of ant species pairs was not random. We suggest that patterns of syconium reproduction and interspecific competition in ants can structure ant communities through niche-partitioning, and highlight three guilds of ants.

A transcriptome analysis of the two types of female florets in *Ficus fistulosa*

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Fig trees are keystone species in tropical forests. Though female florets occur in both male and female figs of dioecious species, differences in their length of styles have a major effect on the fate of wasps that enter the figs. Studies in distylous plants show that differences in style lengths are mainly due to cell elongation. However no genetic work has been done to understand the differences between the two floret types in any *Ficus* species. In this study, we sequenced the transcriptome of the two female floret types in *Ficus fistulosa* on an illumina platform. Sequences were assembled to generate the first *F. fistulosa* consensus transcriptome, which contained 68,083 unique transcripts with a total length of 43.29 Mb. Among those transcripts, 39,323 were annotated, 269 were differentially expressed ($P < 0.05$) and nine GO terms were enriched. Both the auxin and GA signalling

pathways had higher expressions in long-style florets, suggesting their roles in style elongation. Several gene families involved in cell expansion were also found with higher expression in the long-style florets. The floral transcriptome of *F. fistulosa* provides insights into key pathways involved in the regulation of floret development and response to plant hormones. As the first floral transcriptome for a *Ficus* species, our study should facilitate future study of flower development in figs and this is crucial to understanding the evolution of their breeding systems and co-evolution with fig wasps.

After over a century of abstinence, *Ficus elastica* rediscovers sex in Singapore

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The India rubber tree *Ficus elastica* was an important source of latex in the 18th and early 19th centuries, but its importance to latex production was eclipsed by *Hevea brasiliensis* plantations in the late 19th century. Nonetheless, *F. elastica* remains a common ornamental plant. Historical cultivation for latex assisted the spread of *F. elastica* throughout tropical Asia and its provenience has remained a mystery. Moreover, its propagation through cuttings led to the development of asexual varieties, and even those that flowered were never pollinated. Given the absence of evidence of natural regeneration, E.J.H. Corner, the renowned tropical botanist and *Ficus* expert, concluded that *F. elastica* was extinct in the wild. Around 2005, wild seedlings of *F. elastica* began appearing in Singapore and a quick investigation revealed they were being pollinated. The pollinator was identified as *Platyscapha clavigera*, originally described from *F. elastica* in Bogor in 1885. A visit to Bogor Botanical Gardens in 2012 revealed that not only was *F. elastica* being pollinated by *P. clavigera*, but it had probably been reproducing naturally in the gardens for a long time. We suggest that *F. elastica* probably originated from Java, but despite being introduced to Singapore around 200 years previously, it would appear that its pollinator colonised the island only very recently. There are over 50 species of *Ficus* in Singapore, including several closely related species. This illustrates the extraordinary specificity that fig–fig pollinator interactions are capable of maintaining. In addition, through showing that *F. elastica* individuals, which can probably live several centuries, are able to wait for their pollinator over many years, it demonstrates that a highly specific interaction can be extremely stable.

Characterisation of transcriptomes from two development stages female flowers of *Ficus hirta* Vahl. (Moraceae)

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Flower volatile organic compounds (VOC) play important roles in maintaining the specificity of pollinator attraction, yet little is known about the molecular mechanisms of how VOCs achieve this. Fig–fig wasp interactions are ideally suited to address this knowledge gap because they include highly specialised and diversified mutualisms. We present transcriptome sequencing data (RNA-Seq) from two development stages of female flowers of the dioecious fig *Ficus hirta*. To obtain a diverse representation of expressed genes and maximise the yield of VOC-related gene functions, we used illumina paired-end sequencing on female flowers. Approximately 5.6 Gbp and 6.0 Gbp high quality reads were generated for a pre-female phase and receptive phase, respectively. After read trimming, the *de novo* assembly of both reads produced 53,445 unigenes. Eighty unigenes encoding 34 enzymes, containing nearly all enzyme genes of the MVA and MEP pathways, were found to be involved in terpenoid biosynthesis. Regarding the expression level of identified unigenes, 608 were found to be differently expressed in two stages, among which 242 unigenes were up-regulated and 366 unigenes were down-regulated in the pre-female phase. Two genes related to terpenoid biosynthesis, DXS and TPS 14, were significantly lower expressed in the receptive phase. This underlines the need to not only compare DNA structure changes of key enzymes among *Ficus* species, but also to compare their expression levels among different development stages. In addition to the transcript sequences, we designed primers and validated 16 of 56 loci in 30 *Ficus* species. We also identified 133,194 putative SNP. Our results demonstrate the utility of NGS technologies as a starting point for the development of genomic tools in non-model but ecologically important species.

Chemical mimicry: a key process in maintaining a mutualistic network

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Different types of mutualism may interact, co-evolve and form complex networks of interdependences. Although frequently reported, the underlying mechanisms that maintain the stability of such interacting networks are meagre. We surveyed a dominant ant species, the weaver ant *Oecophylla smaragdina*, associated with the fig tree *Ficus racemosa* in Southwest China. *Oecophylla smaragdina* showed tending behaviours to both fig inflorescence branches and treehoppers, but aggressively attacked fig wasps. Treehoppers (*Tricentrus* spp.) had a similar chemical profile to *F. racemosa* inflorescence branches, compared to the cuticular hydrocarbons of *O. smaragdina*, the pollinating fig wasps *Ceratosolen fusciceps* and gall-making fig wasps *Platyneura mayri*. Further experiments showed that cuticular hydrocarbons from both treehoppers and fig branches can protect treehopper nymphs from *O. smaragdina* attack in the absence of a honeydew food reward. Furthermore, *O. smaragdina* captured more non-pollinating wasps (*P. mayri*) than pollinators, as the insects arrived to lay eggs and finally shifted the fig wasp community structure significantly. In this system, the fig is the model, the treehopper the mimic, and the ant the operator: these three species thus form a typical disjunctive chemical mimicry system. This ant–treehopper mutualism indirectly benefits the fig–pollinating wasp mutualism via ant predation of non-pollinating fig wasp species that exert costs on both figs and pollinators. Through simple chemical manipulation, ant–hemipteran mutualism and fig–pollinator wasp mutualism coexist and form a stable interaction. Our results broaden understanding of biological network stability from resource exchange mechanisms to information exchange.

Discriminative host sanction together with relatedness promote the cooperation in fig/fig wasp mutualism

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Sanctioning or punishing are regarded as one of most important dynamics in the evolution of cooperation. However, it has not been empirically examined whether such enforcement selection by sanctioning or punishing, and classical theories like kin or reciprocity selection, are separate mechanisms contributing to the evolution of cooperation. In addition, it remains largely unclear what factors determine the intensity or effectiveness of the sanctions. Here we show that in the obligate, inter-specific cooperation between figs and fig wasps, the host figs can discriminatively sanction cheating individuals by decreasing the offspring development ratio. Concurrently, the figs can reward the cooperative pollinators with a higher offspring development ratio. This sanction intensity and effectiveness largely depends on how closely the host and symbiont are related, either in terms of reciprocity exchange or genetic similarity as measured by the reciprocal of the founders number. Our results imply that in asymmetric systems, symbionts might be forced to evolve to be cooperative or even altruistic through discriminative sanction against the uncooperative symbiont and reward to the cooperative symbiont by the host, i.e. through a game of “carrot and stick”.

Fig wasps, dioecious fig trees and their interactions with fig nematodes

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Several nematodes are associated with the mutualism between fig trees and their pollinating fig wasps. Female

pollinating fig wasps (Agaonidae) can transport nematodes into receptive figs when they enter them to lay their eggs. This study examined the nematodes carried by *Ceratosolen solmsi marchali* into the figs of *Ficus hispida* in Sumatra, Indonesia. *Ficus hispida* is dioecious, with male trees on which pollinator offspring develop and female trees with figs in which only seeds are produced. Male and female trees were regularly sampled to determine the presence of nematodes and infer their ecology. The Baermann funnel method was employed to extract the nematodes from the figs. Three species of nematodes routinely developed inside figs of both sexes: *Caenorhabditis* sp., *Schistonchus centerae* and *S. guangzhouensis*. The presence of nematodes inside female figs has never been reported before, nor have *Caenorhabditis* species been recorded in figs: other *Caenorhabditis* species feed on bacteria. *Schistonchus* spp. are plant parasitic nematodes that feed on female flowers within the figs. *Schistonchus* spp. were transferred mostly as juveniles and occasionally as adults, while *Caenorhabditis* sp. were transferred only as juveniles. Peak populations of nematodes occurred in D-phase figs, when newly enclosed adult female fig wasps were ready to emerge. The nematodes in male figs attached themselves mainly to female pollinators. All three species of nematodes developed successfully in female figs, but had no means of dispersal and no discernible negative impact on seed or pollinator offspring numbers.

Population genetic structure of *Eupristina altissima* in native and colonised regions

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Obligate relationships may restrict the shift in distribution ranges of associated partners with projected climate changes. *Ficus altissima* is a widely introduced fig tree, providing a specific system to study the shift and its potential consequences in the obligate pollinating wasp *Eupristina altissima*. Non-pollinating fig wasps were absent and a cheat (*Eupristina* sp.) was observed in the syconia of introduced *F. altissima* populations. The pollinating wasp *E. altissima* was observed in eight introduced *F. altissima* populations. In this study, we used microsatellite loci to genotype *E. altissima* individuals collected from native and newly-colonised sites to understand the impact of natural colonisation on the genetic structure of the pollinating wasp. As latitude increases, the number of alleles per locus, allelic richness and heterozygosity significantly decreased. Allelic richness and heterozygosity were significantly lower in introduced than native populations. A significant pattern of isolation-by-distance was observed in the studied range, and STRUCTURE analysis indicated a gradient change in genetic composition. Estimated effective population sizes were much smaller in the introduced than native populations. Genetic differentiation was larger in introduced than native populations. These results suggested that founder effect played a critical role in shaping genetic structure in new populations following the introduction of its host plant.

Projecting the effects of climate change on the distribution and diversity of Chinese figs

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Figs (*Ficus* spp.) are one of the most diverse and ecologically important plant genera in tropical forests. Over 750 *Ficus* species are known globally; predominantly from tropical areas although they also extend into the sub-tropics. Global climate change poses a challenge to the future survival and viability of fig species and its potential consequences must be assessed. We projected the effects of climate scenarios by 2070 (RCP 85) on distribution and diversity of 73 fig species across China, and explored changes in range-size. Most species are projected to move north and upslope by 2070, leading to increased diversity in many areas. However diversity is projected to decrease in the south, as southern regions experience novel climates. By including species and records to the south of China, we also expect to see increased diversity in these regions. This highlights the importance of including records from across political borders to improve comprehension. Although future range expansions are projected for generalist species, barriers to dispersal may prevent the expansion of some species (though our projections can be viewed as optimistic for even generalist species). Conversely, future range reductions are projected for many specialist fig species, even if they are able to expand into newly suitable areas. In conclusion, significant changes are projected in the diversity and distribution and diversity of figs across China and the extent of these changes is closely linked to species physiology and the ability of these species to disperse into new areas.

Relationship of pollen traits to pollination mutualism systems and its significance in *Ficus* (Moraceae)

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Pollen traits are related to floral types, pollination syndromes, seed reproduction, breeding systems, and phylogeny. However, systematic pollen data on *Ficus* are rare. Figs are well known for their pollination mutualism with species-specific fig wasps. We investigated the pollen morphologies of 30 Taiwanese fig taxa (including introduced species) using scanning electron microscopy, and analysed the relationships between pollen traits and wasps, breeding systems, pollination models, and life forms. Fig pollen grains are typically symmetrical, diporate, and minutae to perminutae in size. Pollen size differed significantly among subgenera, breeding systems, and life forms. Monoecious figs had larger pollen than dioecious figs and vine species had the smallest pollen of all life forms. Fig pollen size exhibited significant negative correlations with the sizes of pollinating wasps and figs, and larger pollinators were significantly associated with larger figs. Larger pollinators hence carry small pollen grains and enter larger figs. More pollen grains can also be carried by the pollinator for pollinating numerous female flowers. However, pollen size was not significantly associated with seed size, indicating that it was not significantly correlated with seed size reproduction. Moreover, pollen shape could be distinguished into three types (truncate-rhombus, ellipse and truncate-ellipse) conforming to the fig anther/ovule (A/O) ratio. Truncate-rhombic pollen appeared in taxa with a low A/O ratio, indicating that this is carried by actively pollinating wasps. Pollen shapes were related to passive or active pollination modes. In conclusion, fig pollen traits are indicators of pollination syndromes, breeding systems, life forms, and the sizes of pollinators and figs, and these reflect the relationship of pollination mutualism between figs and fig wasps.

The pollinator species complex associated with *Ficus septica* from the Philippines to Taiwan

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The association between figs (plants in the genus *Ficus*) and their pollinator fig wasps is one of the most intricate interactions in nature. It is often described as generally species-specific. Another attribute of this association is that the figs and wasps have contrasting life spans and different means of dispersal. In a complex of islands, such as the Philippines, these traits, along with the presence of large water channels, pose a challenge to the homogeneity of pollinator populations and the specificity of the association. In our study, we looked at how pollinator populations associated with the widespread species *Ficus septica* are structured throughout the Philippines and Taiwan. We extracted and sequenced three genes (COI, cytb, EF1 α) from the pollinator wasps and constructed maximum likelihood trees. Four clades were identified from these trees, three of which only include black-coloured wasps (Mindanao clade, Luzon–Visayas clade and Taiwan clade). The last clade, which we associate with *Ceratosolen bisulcatus jucundus*, includes both black- and yellow-coloured wasps and is distributed throughout the sampling area (south of Philippines up to Taiwan). This provides a general picture of the complexity of the pollinator community associated with *Ficus septica* and an idea of the traits that favour the dominance of one species in a given set of environmental conditions.

What do ants do on *Ficus* trees? Antagonism or mutualism?

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Mutualistic interactions are open to exploitation by one or other of the partners and a diversity of other organisms, and hence are best understood as being embedded in a network of biotic interactions. Figs participate in an obligate mutualism in that figs are dependent on agaonid fig wasps for pollination and the wasps depend on fig ovules for brood sites. Ants have been recorded on approximately 11% of fig species, including all six subgenera,

and often affect fig–fig pollinator interaction through their predation. Two species of fig trees and their associated ant species have been studied in Taiwan since 2009. The colonisation by ants on these fig species displayed a great variability in settlements and activities, with no ant species dominant over others. In Taiwan, ants seem to use figs as a resource when they are at a specific period of their development. Figs can offer distinct types of resources for ants, from fresh new tissues for aphids to wasp prey or even sugars from extra-floral nectaries (EFN). The presence of ants on figs presents in itself a negative impact on the fig and fig wasp mutualism, but EFN are a clue to understanding that the “ant cost” is lower than the negative of parasitic wasps.

Symposium—South and East Asian savannas: poorly understood and under threat

Savannas in Asia: status of a vegetation type and a science

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Research on savannas in Asia has been neglected because until quite recently people perceived them to be either secondary forests or an alternative forest type known as seasonally dry forest. These historical classifications are problematic from multiple perspectives: they ignore the herbaceous layer that is an integral component of these systems and has a unique set of plant species; they fail to recognise that disturbance by fire and/or vertebrate herbivores are intrinsic elements of the systems contributing to ecosystem health and diversity; and they lower awareness that these are distinct vegetation types with unique diversity. As a result, savannas may be poorly researched, weakly conserved, and poorly managed in the region. Here I provide a general overview of the location of savannas in Asia relative to what is observed in other savannas worldwide. I will cover what is known about the historical extent of savannas relative to their present location, and their diversity at local and regional scales. I will also discuss what is known about the drivers of diversity in savanna systems, globally and in Asia. From this it will be apparent that there are large gaps in our knowledge of these systems within Asia. I will further consider their conservation status, present and future threats, and show that current management approaches are weak because we have limited baseline research on these systems. Finally I will lay out a framework for research to improve the status of these unique and important ecosystems across Asia.

Effects of different burning frequencies on fire behaviour and vegetation in dry dipterocarp forest, Thailand

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Anthropogenic burning has become a common phenomenon throughout Thailand. Too frequent fires may affect ecosystem productivity and sustainability. Conversely, complete fire exclusion, may result in changes to ecosystem components and increase the risk of high-intensity wildfires. This study aimed to investigate the effects of burning with different frequencies (seven, two, one and zero fires in the past 10 years) on vegetation structure and composition in dry dipterocarp forest in Huai Kha Khaeng Wildlife Sanctuary, Thailand. Each burning frequency comprised three 30 x 30 m plots. A strip head-fire burning technique was adopted. Fuel loads, fire behaviour and vegetation were investigated. Above-ground fine fuel loads increased with the fire-free interval. However, the rate of fuel load accumulation was not especially high and appeared to reach a steady state after c. 10 years. Despite the greater fuel loads in plots subject to a longer fire-free interval, all of the experimental fires were classed as low-intensity and low-severity. However, fire behaviour varied in both space and time throughout the burning experiment. The structure of stands that had been frequently burned in the past

differed from that of other, less frequently burned stands. Species composition of the small overstorey vegetation in the frequently burned stands also differed significantly from that of the others. The species composition of the unburned site differed from that of the other burning regimes only modestly. Frequent burning also resulted in reduced sprouting capacity of seedlings and saplings. Therefore, fire-free intervals of at least 6–7 years (or 1–2 fires per decade) facilitate the vegetation structure and composition, while maintaining low-intensity fires.

Reinventing the Serengeti of Asia: the savanna forests of eastern Cambodia

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The largest extent of lowland deciduous dipterocarp forest in Southeast Asia occurs across the northern and eastern plains of Cambodia. This landscape historically supported a unique assemblage of megafauna including four species of wild cattle. Biological surveys since the early 2000s have highlighted the continued conservation significance of the eastern portion of this landscape (Eastern Plains Landscape) for threatened birds and mammals. Robust monitoring has indicated the largest global population of banteng *Bos javanicus* (2,000–5,000 individuals), Cambodia's largest known leopard *Panthera pardus* population (>50 individuals), and a landscape-wide Asian elephant *Elephas maximus* population of >200 individuals. The landscape supports significant populations of a suite of large waterbirds and vultures that are characteristic of savannas and deciduous dipterocarp forests but largely extinct elsewhere in Southeast Asia, including the giant ibis *Thaumatibis gigantea*—the national bird of Cambodia. The Eastern Plains Landscape has also been identified as a site for an ambitious tiger *Panthera tigris* restoration project. Deciduous dipterocarp forest in the landscape is species-poor and dominated by *Shorea obtusa* and *Dipterocarpus tuberculatus*, but patches of mixed deciduous and semi-evergreen forest occur through the savanna and are critical refuge habitats for certain species. Important research needs include understanding the roles that ecological and anthropogenic factors, particularly the ubiquitous annual burning, play in maintaining the current matrix of forest types and thus the landscape's global conservation value.

Symposium—Understanding and conserving the diversity and ecology of Southeast Asian bats

Bat Cave Vulnerability Index (BCVI): a method for prioritizing bat caves for conservation and protection

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Identifying key habitats for wildlife is an essential step to plan and promote strategies for long-term conservation. Caves are often overlooked habitats that harbour large numbers of ecologically important species and require serious attention for effective protection. These species include a wide suite of taxa that are adapted to cave environments, but within cave systems bats are key energy providers for other cave-dependent species. In the Philippines, about 78 species of bats are currently known, at least 30 of which depend on caves for their life-histories and survival. The Bat Cave Vulnerability Index (BCVI = PbPg) is an attempt to create a standard index for evaluating bat caves for conservation based on two criteria, the biological (Pb) and geophysical (Pg) potential of caves. The biological potential is represented by the cave bat's community attributes such as population size, species richness, endemism, conservation status and species-site commonness. The geophysical potential is represented by the bat cave's physical and geographical features (accessibility of the cave, cave openings, effort of exploration, tourism potential, presence and intensity of cave internal and external disturbances). Pilot tests in the Philippines show that the index can effectively identify priority bat caves for conservation. Furthermore, the use of BCVI in bat cave assessment could be a valuable rapid assessment tool in cave conservation with special

relevance to bats and cave geological features. We are now trying to apply and adapt the index to evaluate cave vulnerability more widely and develop appropriate protection and management strategies.

Bats of Vietnam: systematics, echolocation and conservation

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The landscape of Vietnam is highly diverse, including various ecosystems in offshore archipelagos, coastal realms, and continental regions. Habitats range from flat land, with urbanised and agricultural areas, to mountainous and karstic regions with tropical forests. Prior to 1997, the bats of Vietnam were poorly studied because the country lacked bat specialists. Since 1998, the author has investigated the bat fauna of Vietnam with particular emphases on taxonomy, echolocation and conservation. To determine the systematics, echolocation and conservation status of Vietnamese bats, the author conducted field surveys through a range of localities across the country. Other actions were also implemented within selected areas for the conservation of threatened species. To date, the achievements include records of species new to Vietnam and discoveries of species new to science, resolving the mysterious hipposiderid taxonomy, insights into unique echolocation systems, conservation of threatened species, and capacity building. This presentation provides an overview of the above achievements with remarks on conservation of flying foxes and a discussion of the development of both academic and conservation programmes in the future.

Black gold: effect of bat guano on the growth of five economically important plant species in Cambodia

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Agriculture remains a core source of income for most Cambodians and fertilisers are critical to crop production and food security. While inorganic forms are primarily used, livestock manure, compost and bat guano are also widely applied. For instance, bat guano has been harvested at sites inhabited by the cave-dwelling *Chaerephon plicatus* for several decades. The creation of roosts colonised by the foliage-dwelling *Scotophilus kuhlii* is also widespread: this practice of establishing bat colonies for on-farm guano collection is unique to Cambodia and small areas of Vietnam. Because the efficacy of bat guano as fertiliser is unknown in Cambodia, we tested this in eight-week growth trials for five economically important species: horseradish tree *Moringa oleifera*, jackfruit *Artocarpus heterophyllus*, longan *Dimocarpus longan*, eggplant *Solanum melongena* and papaya *Carica papaya*. Three treatments were employed: a control, a chemical fertiliser treatment, and a bat guano treatment. Results indicate that bat guano enhanced plant growth. Compared to controls, all species in the guano treatment showed greater growth rates, most of which were statistically significant. Compared with chemical fertiliser treatments, three species in the guano treatment also exhibited greater growth, though only two were significantly different. In the remaining two species, growth was less or similar, but again not significantly different. Additional trials are recommended to elucidate any longer term benefits that might accrue from use of bat guano as fertiliser. Because *C. plicatus* consumes significant quantities of agricultural insect pests, research to determine the importance of agro-ecosystem services provided by *S. kuhlii* is also recommended.

Cave selection and reproductive phenology of insectivorous bats in southern Cambodian karst and their conservation implications

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The ecology and conservation status of cave-dwelling bats is almost unknown in Cambodia. We evaluated

cave selection, reproductive phenology and conservation threats to insectivorous bat species inhabiting three limestone caves (Bat Khteas, Vihear-Tuk Bonn and Trai Lak) in Kampot Province, southern Cambodia. Caves were compared in terms of their internal dimensions and sampled monthly for variation in species composition and flight manoeuvrability from February to July 2014. Bat reproductive phenology was investigated by live-trapping and threats were identified from direct observation, interviews with guano collectors and cave visitor data. The Bat Khteas cave had higher bat species richness (nine species) and larger populations than the Vihear Tuk-Bonn and Trai Lak caves (five species in each) due to its greater size and complexity providing a wider range of environmental niches for different species. Reproductive data from 735 bats of two insectivorous species (*Taphozous melanopogon* and *Hipposideros larvatus*) suggest that birth peaks largely occur in April–May and lactation from April–July, the beginning of the wet season. As this period of heightened vulnerability coincides with the Khmer new year (April) when human cave visitation is greatest, this is likely to affect bat population recruitment. Hunting of bats for bushmeat, opportunistic recreation and unregulated guano collection also threaten the local bat fauna. Improved law enforcement, public education and promotion of sustainable guano collection techniques are needed to conserve the cave bats of southern Cambodia.

Challenges of conserving flying foxes in Peninsular Malaysia

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It is predicted that many pteropodid bats will become globally extinct by the end of this century, with flying foxes (*Pteropus* spp., *Acerodon* spp.) being of particular concern in Southeast Asia due to intense hunting pressure. There is now a widespread consensus that flying fox conservation and monitoring must be prioritised within the region. The urgency of this situation is particularly exemplified by Peninsular Malaysia, where a combination of relentless hunting pressure and agricultural expansion has drastically reduced the numbers of its two flying fox species. This may have negative implications for the country's tropical forest ecosystems because these bats play important ecological roles through long-distance seed dispersal and pollination. Yet this serious decline continues unimpeded due to weak legal protection, negative perceptions of bats, lack of political will, continued demand for flying fox meat, and scant research efforts—a dire situation that is sadly not reflected in the IUCN Red List status of both species. It is clear that immediate conservation efforts are desperately required. However, for conservation to happen, we need to collect quantitative data on ecosystem services and other beneficial aspects of these bats, whilst investigating the issue of bat–human conflict, such as fruit crop raiding, and offering realistic solutions for mitigation. We provide an overview of the situation, and preliminary findings from a PhD project that is attempting to kick-start this conservation process.

Diet of Lyle's flying fox *Pteropus lylei* and potential transmission routes of Nipah virus in Cambodia

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Flying foxes (*Pteropus* spp.) are the reservoir of the Nipah virus (NiV), a zoonotic virus that first emerged in Malaysia in 1998 after spreading to pigs through contaminated fruits. This has subsequently re-emerged annually in humans in Bangladesh since 2001 through contamination of palm sap. The objectives of this study were to collect information on the diet of Lyle's flying fox *P. lylei* and to identify potential routes of transmission from bats to humans or domestic animals in Cambodia. The study included interviews of 110 households around two flying fox roosts in Kandal and Battambang provinces between March and June 2013, and assessments of flying fox diets through analysis of faeces collected monthly at the Kandal roost from December 2013 to June 2014. Of the 110 households interviewed, 20% reared pigs and 50% drank palm juice. Around 75% of villagers had mango trees on their smallholdings and 25% reported that flying foxes eat mangoes. Seven different plant species including mango and sapodilla were identified in faecal samples from the Kandal roost. Given the nature of previous NiV

outbreaks in Malaysia and Bangladesh, our study suggests that mango and sapodilla farming, as well as palm sap consumption, could act as a route of transmission for NiV between bats and humans in Cambodia.

Flying foxes (*Pteropus* spp.) in Cambodia: colony assessments and population dynamics

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Three flying fox species are thought to occur in Cambodia: large flying fox *Pteropus vampyrus*, Lyle's flying fox *P. lylei* and island flying fox *P. hypomelanus*. All three are listed on Appendix II of CITES, but almost nothing is known about their conservation status or population dynamics nationally. We conducted field surveys between June 2013 and August 2014 to assess all of the known or suspected *Pteropus* colonies in the country. We also conducted monthly surveys at one roost in Kandal Province between December 2012 and December 2014 to determine their reproductive phenology and population dynamics. Direct censuses were completed by visually counting the bats during the day, whereas nightly dispersal counts were undertaken at dusk when the bats emerged to forage until all had left the roost site. A total of 13 roost sites were assessed and, despite a measure of protection being provided by certain roost locations (where roosts were near a religious or government building), hunting was commonly reported. Our monthly observations indicate that mating occurs in November and parturition in April, and also suggests that an immigration phase occurs before mating and an emigration phase occurs prior to giving birth. Additional demographic data are needed to design effective conservation plans for *Pteropus* species in Cambodia and Southeast Asia. Further information on population dynamics would also aid understanding of circulation patterns of the different zoonotic pathogens for which *Pteropus* species are a known reservoir.

New perspectives on the ecology and biogeography of Southeast Asian bats

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In a typical Southeast Asian forest, bats can constitute over 50% of the mammal species present, and in Southeast Asia overall they represent around 41% of species. Yet bats rely predominantly on nonvisual cues for interacting with each other and the physical environment, and this may have contributed to the high rate of cryptic speciation (almost 50%). Here I use multiple methods, including molecular analyses, predictive analyses and a variety of other techniques to explore the patterns of diversity, the distribution of different bat assemblages, hotspots of endemism and the biogeography underlying these patterns. I also project into the future to explore the changing patterns of diversity and potential costs of the loss of economically-important bat species for various agricultural sectors within Southeast Asia.

Rice production saving by the insectivorous bat *Tadarida plicata*

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Sustainable rice production is critical to food security especially in Asia. Effective biocontrol of major rice pests such as the white-backed planthopper *Sogatella furcifera* (Horváth, 1899) is hence of eminent importance. We use newly compiled data from Thailand on the wrinkle-lipped bat *Tadarida plicata* (Buchanan, 1800), *S. furcifera* distribution, and an iterative modelling approach to quantify the importance of biological pest control by a common bat species on *S. furcifera*. In Thailand, this single species interaction may prevent the loss of almost 2,900 tonnes of rice per year, which translates into a national economic value of more than 1.2 million USD or rice meals

for almost 26,200 people annually. For the first time, our results show not only the critical importance of bat pest control services in economic terms, but also for sustaining food security. Thus, bat population declines, as currently observed in Southeast Asia, will directly affect people in terms of food and money. Functionally important populations, not just rare and endangered species, should be included in the conservation management of human-dominated landscapes.

Taxonomic implications of geographical variation in *Rhinolophus affinis* (Chiroptera: Rhinolophidae) in mainland Southeast Asia

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Rhinolophus affinis sensu lato is distributed throughout Southeast Asia. The taxonomic status of forms attributed to the species is unclear due to considerable variation in morphology and echolocation frequency. The aim of the study was to evaluate the distribution and taxonomic status of the “subspecific” forms in mainland Southeast Asia using multiple datasets, including morphological, acoustic and genetic data. Three morphological forms were confirmed within the region: two concur with previously recognised taxa, namely *R. a. macrurus* and *R. a. superans*, and were strongly supported by morphological and genetic data. The third form is morphologically distinct but its taxonomic status remains unclear. It is probable that this third form represents a distinct taxonomic entity, but more data are required to confirm this. *Rhinolophus a. macrurus* is known from Indochinese subregion and *R. a. superans* is known from Thai–Malay Peninsula, while the third form is presently known from east-central Myanmar and lower northern Vietnam. Our results suggest that at least three morphological forms occur in mainland Southeast Asia, including one form that appears to be new to science. Echolocation call data for *R. affinis* are not a robust taxonomic tool because they show a significant degree of localised variation that is not supported by genetic and morphological findings. This study highlights significant levels of morphological variation in mainland Southeast Asia and provides an essential basis for further studies to understand the population genetics, phylogeography and taxonomy of the species.

Differential effects of forest proximity on fruit set of tropical tree crops depends on pollination guilds

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Deforestation and forest fragmentation are leading to declines in crop pollinators. To date, studies have focused on the reproductive success and pollination ecology of single crop species at given locations. However, understanding the effect of distance to forest on multiple crop species is necessary because the effect of distance to forest and to cave on pollination services differ for different groups of pollinators such as, for example, insects versus bats. We evaluated flower-visiting animal diversity, visitation frequency and number of fruit set in three species of economic crops: rambutans, durians and mangoes, near (<1 km) and far (>7 km) from the forest edge. The number of fruit set in rambutans was significantly affected by distance to forest, while distance to forest played no role for the number of fruit set in durian and mango. The main visitors to rambutan flowers were stingless bees. The dominant visitors to durian and mango flowers were fruit bats and flies, respectively. The effect of proximity to forest on the number of fruit set varied between plant species. The effect of forest on pollination of each plant species may depend on the visiting animal group. This study provides empirical evidence that not only forest but also caves can act as a source of flower-visiting insects and bats that are potential pollinators for agriculture, and underscores the importance of tropical rainforest and cave conservation for pollination services.

Symposium—Latitude–altitude gradients: inferring the effects of climate change on biodiversity

Using tree-lines to connect altitudinal datasets: progress?

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We collected data on plants and arthropods from eight altitudinal transects in Australia, China and France. Others have similar data from around the world. Almost all datasets show one of several patterns of species turnover from altitude to altitude that throw light on the likely community-level effects of global climate change. To strengthen the conclusions that may be derived from these many data, we seek to overcome the variations in latitude, midpoint elevation and altitudinal range, which vary widely from dataset to dataset. One ecologically realistic approach to this is to re-calculate elevations from the actual or predicted tree-line for that latitude. This enables data from disparate locations to be plotted against a common, ecologically meaningful axis. We have trialled this using a number of diversity measures from, variously, data on moths, ants, leaf miners and trees. All cases generate insights that would not be apparent from single transect analyses. There remain problems associated with sampling methodologies, defining tree-lines precisely and taking into account biogeographic contrasts in phylogenies and diversities. The presentation will outline these results and discuss the advantages and problems of applying this work more widely.

Do butterflies and moths have similar diversity patterns along altitudinal gradients?

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Altitudinal gradients have been frequently used to study environmental effects and mechanisms behind patterns of species diversity and distribution. Papua New Guinea is a biodiversity hotspot with some of the world's largest remaining rainforests. However, there are no data on the altitudinal distribution of key plant and animal taxa. We studied the altitudinal distribution of moths and butterflies (Lepidoptera) along a continuous rainforest gradient from 200 m asl (above sea level) to the forest limits at 3,700 m asl (eight sites, separated by 500 m in altitude) on Mount Wilhelm. With standard light traps and butterfly transects, we recorded 15,000 geometrid moths of 978 species, and 8,800 butterflies of 276 species. Using univariate and multivariate statistics, we show trends in species composition, species diversity and abundance of moths and butterflies along altitudinal gradients, as well as the specific habitat preferences of butterfly species. We provide the first baseline data on the altitudinal distribution of Lepidoptera in Papua New Guinea.

Is climate change inducing range shifts in the tropical birds of Doi Inthanon National Park, Thailand?

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Over the past 100 years, the global average temperature has increased and is projected to continue to rise rapidly. Increased temperature is expected to cause systematic shifts in species distribution. In Thailand, there has already been an increase in average air temperature of 0.95°C between 1955 and 2009, exceeding the average increase of world temperature. However, little is known about the potential extent of climate change impacts on the natural

ecosystems in this area. We addressed this data gap by using abundance data and expected range shifts across elevational gradients to predict change in population sizes in the tropical avifauna of Doi Inthanon National Park in response to climate warming. According to the most conservative model scenario, we find that upland birds are the most strongly affected and are likely to be threatened by increases in temperature. In contrast, the lowland species responded to an increase temperature with increased population size capacity, at least in the short term.

Onwards and upwards: what do latitude and altitude mean to biodiversity in the real world?

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In recent years there has been an increasing use of environmental gradients to explore the distribution of various species and their probable responses to climate change. The velocity of climate change theory states that species need to shift a much smaller distance upslope compared with the large latitudinal distance required to achieve the same shift in temperature. However, studies of the distribution of species on single mountains repeated after several intervals show a convergence at mid-altitudes, rather than a straightforward shift, and transects on mountains at different latitudes do not necessarily show the expected trends. In this analysis, data for around 5,000 species of mammals and amphibians is used to explore the actual interaction of altitude and latitude for given species. Trends within each group are explored at species and family levels and on a regional basis. I also look at other eco-physiological and environmental variables that may drive trends within groups. Ultimately I explore the question: can altitude and latitude be used as scalable alternatives to improve understanding of species responses to climate change, or are other approaches needed to evaluate the effects of climate change on different taxa?

Plotting the future: long-term biodiversity monitoring in Southeast Asia

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Climate change poses one of the greatest and least well understood threats to global forest biodiversity. Long-term monitoring is needed to establish baseline data upon which we can monitor and predict how forest biodiversity and ecological functioning will respond to such anthropogenic disturbances. Here we present our progress to date on the use of elevational “gradsects” which were established along the mountain slopes of different continents to monitor elevational distribution of insects and plants. Data obtained from elevational gradsects provides insights into how organisms are distributed across different elevations under various climatic conditions. The elevational gradsect approach alone, however, cannot encapsulate the ecosystem-level responses to global-scale disturbances due to the practicality of long-term research. CTFS–ForestGEO (Center for Tropical Forest Science–Forest Global Earth Observations) provides an international partnership to establish large-scale ecological monitoring plots where both plants and insects (and possibly other groups of organisms) will be monitored intensively following standardised protocols. Standardised designs ensure that data are fully compatible to a further 61 CTFS plots globally, enabling us to disentangle the effects of local-scale (forest fragmentation, and infestation of invasive species) and global-scale (climate change) anthropogenic disturbances. CTFS–ForestGEO not only boosts scientific understanding of forest ecosystems and their responses to climate changes, but also provides a platform for training and education. CTFS plots have yet to be established in many countries in the Asia Pacific region, and we urge local stakeholders to join such an international partnership.

Potential effects of warming on ant species distribution across elevation gradient in the Eastern Himalaya

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Climate change scenarios for the Eastern Himalayas are predicted to increase in temperature in the near future. We explore the potential effects of warming by comparing communities in early and late summer seasons with small changes in temperature. We use extensive data on ant species communities across elevation gradient in western Arunachal Pradesh, India. The communities were sampled between 200 and 2,400 m, at intervals of 200 m, by extracting them from leaf litter using Winkler bags. We show that species elevation ranges become wider and higher in warmer periods. We also explore the potential effects of these range-shifts on species turnover or beta diversity among communities.

Maximising the resilience of Southeast Asian biodiversity: a South-East Asian Climate Change Adaptation Network (SEACCAN)

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Until recently, habitat loss and degradation was clearly the major environmental threat in the Tropics, but in the 21st century the global climate change poses the greatest challenge we have ever faced. It has never been more important to provide and disseminate knowledge that informs policy and natural resource management that can enable effective adaptation and/or mitigation measures to maintain the resilience of tropical ecosystems and the humans that depend on them. Our goal is to maximise the resilience of biodiversity to climate change in South-east Asia, one of the most significant biodiversity hotspots in the world, by establishing a regional adaptation network of people, organisations and monitoring sites to facilitate research, environmental monitoring, regional capacity building and information exchange across the region. The network will help governments and managers of natural ecosystems to make informed decisions and policies aimed at minimising the negative impacts of global climate change on natural resources and livelihoods. Achieving this goal will require a region-wide collaborative infrastructure that promotes co-operation, reduces duplication and maximises knowledge exchange. We will link the Southeast Asian network with the Australian NCCARF network to create a fully-inclusive Asia-Pacific network that can benefit from the experiences gained from the Australian programme over the last five years. In this talk, we will discuss how this network can benefit all members and invite participation and discussion on the way forward to minimising the impacts of global climate change on biodiversity.

Can species climb away from climate change?

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The Earth's climate has dramatically varied in time, favouring some species while selecting against others. Living in trees has its benefits over life on the ground. Species that can take advantage of increased complexity and resource availability within forest canopies may gain advantages in coping with environmental change. Here we show that patterns of arboreality across an entire bioregional vertebrate fauna in the rainforests of Australia are associated with measures of historical environmental stability. We analysed vertebrate distribution and trait data from 20 years of standardised sampling and compared community-wide trends to historical and current climate models. We found that arboreal species dominate communities in historically unstable areas, and these areas have both low richness and low endemism. Across the bioregion, higher variability and overlap in temperature regimes among rainforest canopies in contrast with the ground suggests that there is less geographic separation in tolerable conditions for arboreal taxa. Exposure and preselection to high temperature variability should allow

arboreal species to exploit climatically uncertain areas, a capacity that may serve them well in responding to future climate change.

NOVEL TECHNOLOGIES IN CONSERVATION

Symposium—Knowing but not seeing: non-invasive DNA sampling for monitoring Asia’s threatened biodiversity

Conservation at the blunt end: DNA as a conservation tool rather than an academic discipline

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Analysis of DNA offers a useful tool for studying the evolution, ecology and demographics of wildlife species, particularly when the species is rare, elusive or just difficult to study in the wild using alternative approaches. Despite being present in all animal cells, the quantity and quality of DNA varies depending on the starting material: cells harvested from live or freshly killed animals can provide an infinite supply of DNA for analysis; however, at the other end of the spectrum, cells recovered from faecal samples are few in number and are significantly outnumbered by exogenous DNA and frequently compromised by environmental conditions and time to isolation. We need to improve our approaches for recovering and analysing DNA from such low quality samples as we are frequently relying on antiquated techniques from the 1990s. Additionally, conservation practitioners are regularly hostages of academic departments and their expensive laboratories to undertake DNA analysis: a forced collaboration and subsequent data surrender that is not always to the benefit of a field programme. The complicated wet lab chemistry of DNA preparation and analysis is generally less important now and modern approaches can offer a black-box approach for conservation practitioners to generate their own data, even from difficult samples such as faecal samples. By ensuring field collection techniques are correctly experimentally designed, DNA isolation is targeted and maximised and appropriate DNA markers are utilised for specific conservation or ecological questions, DNA analysis can become the conservation tool it should be: inexpensive, rapid, accessible and informative.

Endangered and unseen: using leeches to survey mammalian biodiversity in the Annamites

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Rare or elusive mammals living in tropical forest are difficult to detect. Our lack of knowledge of these species hinders effective conservation action. The Annamites ecoregion contains several endangered and endemic mammals that are difficult to detect and therefore poorly studied. It has recently been shown that DNA extracted from the guts of terrestrial haematophagous leeches can be sequenced and identified to host species. This new method shows great promise for surveying hidden components of mammalian tropical biodiversity. However, the path from promising method to effective survey technique is not straightforward. Between 2012 and 2015, leech surveys were conducted in Vietnam and Laos. We present preliminary results that show the potential for leech surveys in: (i) low-intensity surveys conducted over medium to large spatial scales with the objective of assessing broad mammalian biodiversity; (ii) intensive surveys conducted in targeted areas and at smaller spatial scales with the objective of detecting rare species; and (iii) systematic point-sampling with the objective of

gathering data that can be analysed in more statistically robust ways. Our results indicate that leech surveys can be used for baseline monitoring of mammalian biodiversity and to detect rare species. Our findings also show that terrestrial leeches feed on a wide range of taxa and have the potential to present a detailed cross-section of the Annamites mammalian community. Future studies are needed to further refine this survey method.

Faecal DNA-based methods for monitoring wildlife populations: opportunities and challenges

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Faecal DNA-based monitoring methods (especially capture–mark–recapture methods) can provide more precise abundance estimates, and more data about population structure and dynamics, than conventional methods such as dung density-based methods or sighting-based methods. Faecal DNA-based capture–mark–recapture methods typically also require less time in the field and can be used when dung density or other methods are impracticable. In addition, as the laboratory costs associated with faecal DNA-based methods have fallen, these methods are now often cheaper than conventional labour- and/or time-intensive methods. Nevertheless, a number of challenges remain, including: the limited number of laboratories able to conduct the work required to a high standard; restrictions on sample exports that further limit the number of available laboratories; the difficulty of predicting the number of samples required, which affects both sample design and budget predictions; appropriate sample preservation/storage; and how to maximise sample quality in the field. Fortunately, a number of recent developments are reducing the significance of some of these challenges: these developments are reviewed and the remaining issues are discussed as an aide to selecting the most appropriate monitoring methods for elusive species in challenging environments.

PCR-free mitogenomics for high-throughput monitoring of bee diversity

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Wild bees play a keystone role in the pollination of wild plants and cultivated crops and thereby help to maintain biodiversity and increase food production. We require high-throughput methods to monitor bee abundance and diversity because the number of wild bee species ranges from hundreds to thousands per country. Morphology-based identification and PCR-based metabarcoding are inefficient because taxonomic expertise is scarce, and the Hymenoptera are recalcitrant to PCR. We used a metagenomic approach to identify bee species from bulk samples. Reference mitochondrial genomes from 48 bee species were assembled, and 10 bulk samples containing a total of 204 bees in 33 species were shotgun-sequenced, and the sequence reads were matched to the reference mitogenomes. The re-sequencing dataset showed high accuracy, successfully identifying 59 out of the 63 total species in the morphological dataset (four were false negatives). The two datasets returned indistinguishable estimates of community structure and total species diversity, and read-number was positively correlated with estimated species biomasses. Mitogenomic resequencing can easily be extended to other important taxa.

Using bulk mosquito samples to detect vertebrates

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Invertebrate parasites of mammals (leeches, flies, ticks, and mosquitoes) are carriers of vertebrate DNA and can be used to detect the presence of vertebrates (known as 'iDNA'). To date, mosquitoes have not been well-studied for this purpose. Here we present results showing that high-throughput sequencing of 16S amplicons from bulk mosquito samples can be used to detect a broad range of vertebrates, including herpetofauna, mammals, and birds. We present details of our laboratory and bioinformatic methods, including the use of emPCR.

Using leeches to monitor and detect cryptic mammals from Laos and Vietnam

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We report on the results of a collaborative project with the Saola Working Group in which we have applied high-throughput sequencing of 16S amplicons to bulk leech samples collected in Vietnam and Laos. The output is a list of mammal species, many of which are otherwise difficult to detect because they are rare, small, nocturnal, or arboreal. We discuss the laboratory and bioinformatic pipelines that we used to process the samples.

Monitoring Mondulhiri's elephants—the use of non-invasive genetic sampling for conservation

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There has been a dramatic increase in the application of population genetics and use of genetic tools in conservation biology over the last decade, predominately due to improved methods and reduced costs. Extracting DNA from faecal samples has proved invaluable, particularly for cryptic species, those occurring in low densities, and those with large home ranges or areas of distribution. This makes it the most suitable approach for monitoring Endangered Asian elephants *Elephas maximus*, in particular Southeast Asian elephants, which meet all of the criteria and predominately occur in dense evergreen and semi-evergreen forests. The Wildlife Conservation Society (WCS) and WWF Cambodia work in three protected areas that form the majority of the Eastern Plains Landscape (EPL)—a contiguous network of protected areas covering over 1,000,000 ha. WWF and WCS conducted three independent non-invasive faecal DNA surveys of Asian elephants over the last nine years, in collaboration with government partners. Results from capture–recapture models estimate populations of 136±18 (SE) in Phnom Prich Wildlife Sanctuary and 116±9.79 (SE) in Seima Protection Forest. Unfortunately no elephants were recaptured in MPF, thus the 21 individuals identified are used for minimum population estimates. These results suggest that the EPL is likely to have the largest meta-population of elephants in Cambodia, thus supporting that this landscape is regionally important for elephant conservation. Based on the success of this approach, WWF and WCS will conduct a joint survey that will produce the first simultaneous robust estimate of elephants across the majority of this landscape.

Symposium—Ex situ plant conservation in tropical Asia

Asymbiotic seed germination and in vitro seedling development of *Paphiopedilum spicerianum*: an orchid with an extremely small population in China

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Paphiopedilum spicerianum is a terrestrial or lithophytic orchid and it is listed as one of China's wild Plant Species with Extremely Small Populations (PSESP). Procedures were developed for asymbiotic seed germination and seedling development aimed at producing seedlings for re-introduction. Of the six germination media pretested for protocorm formation, two gave viable protocorms: one-quarter strength modified Murashige and Skoog (MS) medium and modified RE media supplemented with 10% coconut water (CW). The highest germination was achieved in RECW with a 24 h dark cycle after pre-treatment with 1% NaOCl for 40 min. However, these protocorms remained white and did not develop further. Although germination was lower under the same conditions in MSCW, it resulted in healthier and greener protocorms. Of four suitable media tested to promote seedling formation, Hyponex No 1 medium with 1.0 mg l⁻¹ α -naphthlene acetic acid, 0.5 g l⁻¹ activated charcoal and 10% banana homogenate was the most effective. Advanced seedling development was seen in all six tested media during a 4-month growing period, with the highest leaf growth rate seen in the same media used for seedling

formation, supplemented with 1.0 mg l-16-benzyladenine added to promote leaf growth. Fluorescein diacetate (FDA) tests on seeds showed that higher salt concentrations in the medium and longer duration of exposure to NaOCl reduce germination because of damaging effects on the testa and the embryo cells. We recommend the use of the FDA test and UV imaging as a pretest for assessing suitable conditions for the seed germination.

Conservation of sub-tropical rainforest seeds—can they be banked?

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Seed banking is an effective conservation technique for species with seeds that tolerate desiccation and long-term storage at -20°C. However, many rainforest species are expected to produce seeds that do not tolerate desiccation. Those that tolerate desiccation may not tolerate freezing or may be comparatively short-lived in storage at -20°C. We investigated desiccation and freezing tolerance in sub-tropical Australian rainforest species by comparing the germination percentage of fresh seeds to that of dried seeds and seeds stored at -20°C after drying. We then tested the comparative longevity of seven species that had retained their viability following freezing (germination \geq 84%). Seeds of these species were rehydrated for two weeks at 20°C and 47% relative humidity, then artificially aged at 45 \pm 2°C and 60% relative humidity. The number of days in the aging environment required to reduce germination by 50% was estimated by Probit analysis in GenStat v11. Of 76 species for which unambiguous results were obtained, 31 species (41%) had seeds that were desiccation-sensitive. Of 24 desiccation-tolerant species tested further, the germination of approximately one-third was substantially reduced by freezing and thawing. Six of the seven species suitable for seedbanking proved to be comparatively short-lived under artificial aging conditions (p_{50} < 11 days). The high proportion of rainforest species that were desiccation-sensitive, freezing-sensitive or short-lived indicates that alternatives to standard seedbanking are likely to be required for ex situ conservation of the majority of plants from sub-tropical rainforests.

Kew's Millennium Seed Bank Partnership: safeguarding Asia's plant diversity for the future

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The Millennium Seed Bank Partnership (MSBP) is an ambitious plant conservation project that addresses the Global Strategy for Plant Conservation (GSPC) Target 8: "at least 75% of threatened plant species in ex situ collections, preferably in the country of origin, and at least 20% available for recovery and restoration programmes". The MSBP has now banked 13% of the world's bankable plant species, and aims to have banked 25% (some 75,000 species) by 2020. This is being achieved by working in partnership with at least 80 countries around the world and banking seeds in-country, with duplicate backup collections held at the MSB or other approved facilities. Seeds are collected according to strict protocols that preserve genetic diversity and integrity, and are banked under optimum conditions to maximise viability. So far, relatively few species have been collected from tropical and sub-tropical Asia, despite the region being home to seven biodiversity hotspots. However, the MSB is now developing a seed conservation programme for Asia: current projects focus on crop wild relatives and endangered trees, and there are plans to broaden the scope further. This new initiative aims to ensure full coverage of floristic regions, address urgent conservation needs and, essentially, link in with in situ conservation and restoration projects to ensure that seeds can be used to safeguard Asia's native plant diversity.

Genetic optimisation of the living collection for threatened plant species in Xishuangbanna

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Xishuangbanna is a plant diversity hotspot, supporting 10% of China's angiosperm flora. Agricultural expansion in recent decades had resulted in habitat loss and fragmentation, driving many plant species towards extinc-

tion. To ensure the long-term survival of threatened plant species, the Center for Integrative Conservation in the Xishuangbanna Tropical Botanical Garden (XTBG) has initiated a “Zero Extinction Project”. Central to this project is the ex situ conservation of threatened species, many of which will be included in the living collection within XTBG. Efficient management of the living collection requires that the total genetic diversity of a species is represented by the least number of individuals within the collection. Hence there is a need for a genetic screening method that is: (1) rapid; (2) applicable to many angiosperm species; and (3) sufficiently cost-effective that large numbers of seedlings can be genotyped. In this study, I aim to develop a genetic screening protocol using Next Generation Sequencing technologies for the genetic optimisation of threatened plant populations for ex situ conservation. Specifically, I will utilise target enrichment methods to obtain a reduced representation of the genome and optimise the protocol for maximum multiplexing capabilities. The resulting genetic protocol will enable the living collection in XTBG to capture the maximum amount of genetic diversity present in the wild population. This study has far-reaching implications: besides enabling XTBG to extensively increase the capacity of its living collection without a substantial investment in space, it also has the potential to be the gold standard for genetic optimisation for ex situ conservation. Currently, the “Zero Extinction Project” initiated by XTBG has been replicated in other botanical gardens in China. Therefore, the methodology developed in this study will also be adopted by these botanical gardens in the near future. In summary, this study represents a large technological step forward in the ex situ conservation of tropical plant species and is essential to XTBG’s position as a pioneer in plant conservation.

Ex situ plant conservation in tropical Asia

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The fragmentation of tropical forests determines the change in ferns species composition, particularly species sensitive to the change in microclimatic conditions. Despite ferns producing abundant spores, in tropical forests many species tend to occur in small and isolated locations. For example, many studies show that along altitudinal gradients, more than 40% of fern species are recorded only once. Deforestation and fragmentation processes can drive ferns, particularly species with small populations, towards local extinction. In this regard, ex situ conservation, including spore banks, could make a potentially positive contribution to preserving the endangered species. The ex situ conservation of these vascular plants is only recently becoming a subject for research and applied projects. Here I present the effects of forest fragmentation on fern species diversity in the tropical and subtropical ecosystems of Xishuangbanna, Yunnan, China. Xishuangbanna is at the fringe of the tropical Indochina Peninsula in China, with approximately 20% of the country’s flora in only 0.2% of Chinese territory. The study focused on first, the influence of forest fragment size on fern diversity and second, the importance and the potential strategy of ex situ and spore bank conservation for fern species conservation. Preliminary results show a rich fern species diversity for the entire study area, but underline the extinction risk for many sensitive fern species due to forest conversion. I will also present the preliminary results of assessing the conservation status of tree ferns in Xishuangbanna and the potential for ex situ conservation.

Symposium—Evolution and biodiversity in tropical Asia

An integrated approach to understanding the assembly and evolution of biotas: a case study from the Amazon

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Amazonia is one of Earth’s most iconic hotspot of diversity and endemism and one of the most important terrestrial

biomes for its contributions to global systems ecology. To understand the importance and future of Amazonian biodiversity to Earth's systems biology, it is crucial to place the present-day Amazonian biome in its historical context. Our understanding of how Amazonian biodiversity has been generated and assembled taxonomically and ecologically remains surprisingly meagre, as is knowledge about how Amazonian ecosystems have responded to historical environmental change. There are also major uncertainties about the paleogeography, age, and extent of its immense freshwater and terrestrial ecosystems. Some models posit that these ecosystems were established in the Middle to Late Miocene, whereas others see them as being Plio-Pleistocene in age. Resolving these historical uncertainties, as well as addressing how biotas within Amazonia have responded to past paleogeographic and climatic events, have major implications for understanding past and present environmental change, for predicting the future of ecosystem structure and function at different spatiotemporal scales, and for understanding the generation and maintenance of biodiversity.

An assembly and alignment-free method of phylogeny reconstruction from next-generation sequencing data

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Understanding the phylogenetic relationships among organisms is essential for understanding ecological, biogeographical, and evolutionary questions, and conserving biodiversity. Currently, the simple step of generating a robust phylogeny for a group of poorly studied organisms can require substantial research investment. Next-generation sequencing technologies are rapidly generating whole-genome datasets for an increasing number of organisms, most of which are understudied non-model organisms of ecological or evolutionary interest. However, phylogenetic reconstruction of genomic data remains difficult because *de novo* assembly for non-model genomes and multi-genome alignment are challenging. To greatly simplify the analysis, we present an Assembly and Alignment-Free (AAF) method (<https://sourceforge.net/projects/aaf-phylogeny>) that constructs phylogenies directly from unassembled genome sequence data, bypassing both genome assembly and alignment. Using mathematical calculations and sequence simulations, we address both evolutionary and sampling issues caused by direct reconstruction, including homoplasy, sequencing errors and incomplete sequencing coverage. As a test case with real data, we successfully reconstructed the phylogeny of 12 mammals using raw sequencing reads. We also applied AAF to 21 tropical trees with a focus on Fagaceae and *Ficus* (Moraceae); two important tree groups in Southeast Asia. This dataset consisted of sequencing reads with low coverage and short length, but was sufficient to reconstruct the phylogeny, and provide new insights into the evolutionary history, of those groups. Our AAF method opens up phylogenomics for species without an appropriate reference genome or high sequence coverage, and rapidly creates a phylogenetic framework for further analysis of genome structure and biodiversity among non-model organisms.

Host specificity in tropical insect herbivores in phylogenetic context: methods and examples from New Guinea rainforests

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Host specificity is a key parameter in the dynamics of plant-insect food webs, but also a phylogenetically constrained result of the plant-herbivore evolution. These two perspectives favour different measures of host specificity, taking into account the phylogeny of hosts, or both hosts and consumers, or neither of the interacting taxa. Here we describe new host specificity measures incorporating host phylogeny and apply them to extensive data on plant-insect food webs from the New Guinea lowland rainforests. We are using these results to discuss the ecological importance of host specificity, particularly for the possible role of herbivores as density-dependence agents maintaining the diversity of tropical vegetation.

Comparative biology study of plant adaptive evolution responding to climate change among genus *Ilex* in Yunnan, Southwest China

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The genus *Ilex* in the phylogenetically-isolated monogeneric family Aquifoliaceae is the largest woody dioecious clade, with around 700 species. The geographical distribution of *Ilex* is strongly constrained by drought or prolonged sub-zero temperatures, suggesting that climate exerts a major control on species distribution. Extant *Ilex* diversity is concentrated in mesic East Asia and montane South America. China has 204 species (149 endemic), especially in subtropical evergreen broadleaf forests in the south. Yunnan has the highest diversity with 91 species at provincial level. The genus *Ilex* is morphologically diverse in Yunnan, varying widely in growth form, leaf size and morphology, and both flower and fruit characteristics. This project will investigate the evolutionary diversification of *Ilex* in Yunnan, using a combination of molecular phylogenetics, functional traits, and field observations of environmental requirements. Further studies will aim at predicting the potential impacts of the ongoing, anthropogenic, climate change on the future survival and distribution of *Ilex* species in Yunnan.

Effects of teak plantation and agroforestry on forest snail communities in Java

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Java is the most populated island in Indonesia and has suffered a massive land use change over time. We studied land snail communities in four different land use types: agroforestry, teak plantation bordered with agroforestry, teak plantation bordered with natural forest, and natural forest, in South Malang, Java. We aimed to reveal the effects of different land uses on the richness and composition of snail communities and to identify additional environmental variables that influence the richness and composition of snail communities. Ten plots of 10 × 10 m were selected randomly in each land use type. Two researchers searched for living and dead snails and slugs for one hour per plot and also collect 5 litres of soil and leaf litter samples: 2,919 specimens were recorded and were assigned to 55 species and 21 families. Species richness and abundance were highest in the natural forest followed by the teak plantation (with regard to richness) and agroforest (with regard to abundance). Land use type had the strongest influence on the composition of snail communities. Other variables with a significant impact were altitude, canopy cover, amount of leaf litter, human impact and presence of deadwood, stones and bare rocks. The number and abundance of introduced species was higher in the agroforestry and teak plantation sites, whereas the number and abundance of prosobranch species was highest in natural forest. Altitude was the only variable that significantly influenced species richness across plots. The study suggests that further conversion from natural forest to other land use types will significantly affect the forest snail community.

Floral and reproductive ecology of *Cycas panzihuaensis*

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Cycas panzihuaensis L. Zhou & SY Yang is endemic to China and occurs only along the Jinshan River and its tributary valley, which forms the northernmost natural distribution of cycads. Previous observations suggested that *C. panzihuaensis* should depend on wind pollination, although the female and male cones emit an odour, and the male cones host a large number of small beetles during the flowering time. In addition, this species suffered from pollen limitations under natural pollination. To fully understand the reproductive biology of *C. panzihuaensis*, we examined its mating system and observed its floral biology, including floral visitors, ratio of female/male

cones, chemical components of floral odour, and floral thermogenesis. In this study, we found that the chemical composition of female/male cones flowers includes 1-methoxy-4-(2-propenyl)-benzene. The temperature of both cones rises during the day, while male cones have a sudden warming process at night from 1900 to 2300 h. Ratios of female/male cones at Geliping and Houzigou were 1:2.14 and 1:2.43, respectively. A lot of beetles were found in male cones. This species was identified as a species of Melyridae using a COI barcode. Bagging treatments indicated that wind-pollination played an important role in seed production of *C. panzhihuaensis*. Because the seed-set of *C. panzhihuaensis* heavily depends on the neighbouring male cones, habitat fragmentation may reduce reproductive success.

Multiple factors contribute to reproductive isolation among four coexisting *Habenaria* species (Orchidaceae)

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The relative importance of different types of reproductive isolation among closely coexisting species has become a central topic in the study of speciation. However, only a few studies have considered the full range of pre- and post-zygotic barriers that limit gene flow between coexisting plant species. Here, we documented the distribution, floral biology, pollination process and breeding system of four coexisting orchid species of the genus *Habenaria* to assess the components of their reproductive isolation mechanisms. Among these orchids, overlapping floral periods were observed between *H. davidii* and *H. fordii*, and between *H. petelottii* and *H. limprechtii*, respectively. Therefore, the different population flowering periods were responsible for reproductive isolations between these two species pairs. *Habenaria davidii* and *H. fordii* had overlapping habitats and shared one pollinator, but the non-matching mechanisms between the caudicle and stigma could reduce pollinaria exchanges between these two species. This indicates that floral isolation has played an important role in the pre-zygotic reproductive isolation. However, a low fruit set was observed in the inter-species crossing treatment, which suggested that the pre-zygotic isolation might be incomplete, and post-zygotic isolation also worked. *Habenaria petelottii* and *H. limprechtii* occurred in the different altitude habitats and had different pollinators. There was no significant difference between the fruit set in inter-species crossing treatment and that in the selfing treatment. These results showed that the combination between microhabitat isolation and floral isolation could form the pre-zygotic reproductive barriers between these two species. Considering these multiple factors contribution to reproductive isolation in these four closely coexisting orchids, there could be a balance between pre-zygotic and post-zygotic isolations.

The coupling of tropical Asia–North Pacific in cold water coral fauna

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Many studies have focused on tropical water fauna. However, influences of tropical elements on biodiversity in North Pacific cold-water fauna have received much less attention. The questions are: (1) how far can tropical water elements influence northern fauna; and (2) is there any exchange between these two oceanic regions? The theme of tropical Asia–North Pacific coupling in cold water coral fauna acknowledges that there is at least a one-way traffic from south to north between the tropical coral fauna and the northern deep-cold water coral fauna. The North Pacific cold water fauna include many tropical elements. The centre of diversity of octocorals (Octocorallia, Anthozoa, Coelenterate) is located in tropical Asia, but 56% of all octocoral species ($n = 146$ species) that occur in Sagami Bay (33–35°N latitude) in front of Japan's capital city, Tokyo, are Indo-Pacific (tropical) elements. Here, I focus on more northern cold-water coral fauna up to 39°22'N latitude, in Otsuchi Bay in the Sanriku region on the Northwest Pacific side of Japan. The water temperature of this region is between 4°C and 22°C. Despite its cold water environment, nine (44%) of its coral species comprise tropical elements. These results suggest that tropical water contact with the north deep-cold water is significantly greater than has been suggested by previous studies.

Urban blues: birds change their tune in noisy cities

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Habitat loss is the main driver of global biodiversity declines and urbanisation is a growing cause of habitat loss, nowhere faster than in Asia. Urban habitats differ from the habitats they replace in many ways, altering the selective environment for urban dwelling species. Understanding which species are able to adapt to these novel conditions is therefore essential to conserve biodiversity. High levels of low frequency traffic noise in cities potentially mask animal communication signals, interrupting important functions such as mate choice and territory defence, and ultimately decreasing fitness in urban birds. We examined the relationship between background noise and song structure to test the hypothesis that birds need to sing higher in cities to avoid masking. We have now recorded urban and rural songs of five species of birds, all of which use different frequency ranges and vary in their ability to learn songs. We found a strong correlation between background noise and minimum frequency in four of the five species, supporting the hypothesis that elevating frequency is a response to background noise. The species which does not learn its songs also sang higher in noisy areas, suggesting that this may not be simply a plastic behavioural response, and that birds may be evolving to live in cities. The consequences of such song modification are not yet well understood and future studies will focus on the fitness of urban dwelling birds with altered songs.

***De novo* assembly of *Firmiana danxiaensis*, an endemic tree species of the Danxia landform**

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Many *Firmiana* species are locally endemic, presenting an interesting system to study adaptation and speciation. Moreover, *Firmiana* species are also traditional medical plants, and their leaves are high accumulators of heavy metals. Among these species, *F. danxiaensis* is a tree endemic to Mount Danxia, famous in the Danxia landform. How it could adapt to the stressful environment of rocky cliffs and barren soils in the Danxia landform was unknown. In this study, we *de novo* assembled the transcriptome of *F. danxiaensis*, providing 45,815 unigenes with a N50 value of 1,216 bp. Homology analysis showed that 35,054 had hits in the NCBI non-redundant database, and 27,626 of them had the best hits with *Theobroma cacao*. Gene ontology annotation showed that hundreds of unigenes took part in responses to various stresses or nutrition starvation, suggesting that they may be helpful for the adaptation of *F. danxiaensis* to Mount Danxia. Clusters of orthologous groups and Kyoto Encyclopedia of Genes and Genomes (KEGG) annotations revealed lots of genes playing roles in the biosynthesis of secondary metabolites, especially flavonoids and cumarins, providing potential keys to looking through the medicinal roles of *Firmiana*. Additionally, we found 477 genes related to responses to Cd, which partly explain the high accumulation of Cd by *Firmiana*. Based on this transcriptome, we further identified a *Firmiana*-specific whole genome duplication event occurring at approximately 20 Mya, which may provide raw materials for the diversification of *Firmiana* species.

Control of final organ traits in *Machilus* species

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Seed dispersal is vital to the plant life cycle. The majority of plants rely on vertebrate frugivores to disperse their seeds by offering a reward for swallowing them in the form of fruit. Fruits with single-seeded, globose, brightly coloured, berry traits are considered the first choice of frugivorous birds in most cases. In the tropical montane zone of Southeast Asia, Lauraceae is more abundant and more likely to reach the top layer of forest canopies than another woody family, Fagaceae. The fruits of Lauraceae always attract frugivorous birds such as birds of paradise and bell birds. It seems that the close relationship between Lauraceae species and their frugivorous birds

could affect their functional traits. Here, we choose the species of *Machilus* and *Phoebe* genera to test the assumption that co-evolution with seed dispersers has driven the organ traits.

The taxonomical diversity of family Zingiberaceae in Luang Prabang Province, Lao PDR

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A study of the diversity of the family Zingiberaceae in Luang Prabang Province in northern Laos was conducted from 2010 to 2014. The field team collaborated with Dr Jana Leong Škorničková (Singapore Botanic Garden) and staff from Queen Sirikit Botanic Garden. Plants, photographs, living specimens and herbarium specimens were collected during the field work. The living collections were planted in Pha Tad Ke Botanical Garden for ex situ conservation and for further study. Based on taxonomical literature studies and some catalogues of type specimens, sheets were deposited online at the Muséum National d'Histoire Naturelle in France and the Royal Botanic Gardens of Edinburgh and the Royal Botanic Gardens, Kew, in the UK. A total of 99 specimens were collected and identified to 43 species in nine genera. Twenty-four species were brought from the forest to cultivate in domestic gardens for medicinal, vegetable and ornamental purposes. Eleven species were new to science and occur in Laos. One species endemic to Luang Prabang is *Curcuma corniculata* Škorničk. In further studies, more field collections will be made and plant morphology, pollen morphology and DNA will be examined. Additional funding is needed to support this field work.

SUPPORTING HUMANS AND BIODIVERSITY

Symposium—Conservation education: building capacity for conservation in Southeast Asia

Combating the wildlife trade through community engagement

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Cambodia is a source, transit point, and destination for the illegal wildlife trade. Valued at an estimated US\$ 10–20 billion annually, wildlife trafficking is one of the most lucrative black market trades in the world. Combined with habitat destruction, wildlife trafficking is rapidly pushing many species to extinction. Demand in Asia for wildlife and their products for use as meat, traditional medicine, exotic pets, and trophies fuels the trade. Lack of environmental education and knowledge of Cambodia's wildlife laws limits the ability to restrict the supply. To address these challenges, Wildlife Alliance takes a multi-pronged approach to conservation that addresses both the supply and demand of the illegal wildlife trade. This is done through wildlife law enforcement, habitat protection, sustainable economic development, and public outreach to educate Cambodians about their natural heritage. Wildlife Alliance created Cambodia's only mobile environmental education and community outreach team, the Kouprey Express, to raise awareness about wildlife protection and Cambodia's wildlife laws. The Kouprey Express visits schools and rural communities nationwide to conduct interactive hands-on student lessons, teacher and community trainings, public outreach events, and billboard campaigns. These grass-roots efforts of the Kouprey Express are building a constituency for the conservation of Cambodia's biodiversity heritage and changing behaviours towards wildlife and their habitat. Over 60,000 live wildlife animals have been rescued from the illegal wildlife trade as a direct result of the Kouprey Express and Wildlife Alliance's combined efforts.

Developing capacity for wildlife and protected area management in Lao PDR and Vietnam

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Declining biodiversity in Southeast Asian protected areas is attributed to unsustainable exploitation of natural resources. A significant underlying factor is the lack of capacity for sustainable and effective wildlife and protected area management. There is a strong need to develop the technical capacity of academic and professional training programmes to build a cadre of adequately trained individuals with relevant knowledge and skills. We describe parallel approaches implemented in Lao PDR and Vietnam over the past decade to build capacity within training institutions and in individuals responsible for protected area and wildlife management. The initiative has involved international institutions (the American Museum of Natural History and Wildlife Conservation Society) working in collaboration with national institutions such as the National University of Lao PDR and the Centre for Natural Resources and Environmental Studies in Vietnam. We evaluate the effectiveness of the approaches, review implementation outcomes and identify critical challenges for capacity development within a broader context of evolving donor and host country institution priorities. Lessons that have emerged include the need for strong linkages between organisations implementing field conservation, professional training institutions and government agencies. This is necessary to ensure relevance of training to practical field needs and address baseline capacity limitations. Further, there is a need to develop more rigorous, measurable, and impact-focused systems for evaluation of capacity development investments. Beyond the engagement of international institutions, the sustainability of capacity building initiatives is largely conditional on the commitment of host-country institutions within a supportive government policy framework.

Changes in publication rates and the research productivity of tropical countries in conservation science: implications for inclusive conservation

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It is indisputable that tropical countries hold the most biodiversity in the world and that tropical biodiversity faces particularly high threats. Yet because most tropical countries have historically been underdeveloped, much of the research in conservation science has come from the outside. Here we ask whether economic development over the last 30 years, and changes in the publishing industry, have affected the research productivity of tropical and/or non-high income (NHI) countries. An analysis of data from SCImago demonstrated that conservation science was slightly beneath average in the proportion of publications contributed by NHI countries in 2013 and lagged substantially in the change in this measure over time. A literature review of 740 articles, found that approximately 50% of the recent research (2006–2012) in tropical countries was conducted by temperate institutions: down from 57% in 1980–1990, but unchanged from 1995–2003. Data from 12 conservation journals showed that the acceptance rate for the five largest contributing NHI countries was approximately 0.55 times that of the largest HI countries. Although the link between publications and actual conservation action is debatable, we see potentially negative effects of low research productivity in the tropics. This includes a “brain-drain” of the best young scientists, which is important to conservation if local actors are more effective, and a lack of awareness about the importance of conservation.

Community-led nest protection and pagoda-based head-starting of Cantor’s giant softshell turtle in Cambodia

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Since 2007, Conservation International (CI) has worked with local villagers living along the Mekong River in

Cambodia to conserve the Cantor's giant softshell turtle *Pelochelys cantorii*. Listed as Endangered on the IUCN Red List, the species had been considered extinct in Cambodia and was rediscovered only in 2007. Through CI's programme, turtle nests are protected from Sambor District in Kratie Province to around 40 km upstream on the Mekong River. From 2007–2014, 224 nests were found and protected by villagers with 5,583 hatchlings produced successfully and released into their habitat. CI has also collaborated with monks from the historic 100 Pillar Pagoda to construct a turtle 'head-starting' facility. This included rebuilding an old pond and constructing a turtle facility in the pagoda grounds in 2011, named the Mekong Turtle Conservation Center (MTCC). The MTCC is being used for community education and ecotourism, and to raise hatchlings to 10 months of age before being released. The monks help to disseminate awareness of the turtle conservation programme to tourists and local school students. The MTCC is used to train community nest protectors on how to take care of the turtle hatchlings and other native turtle species. The MTCC attracted over 3,000 national and international tourists in its first year.

Developing key skills for the next generation of conservation ecologists

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The parts of the world with the greatest need for conservation are also those with the least access to training in essential skills to understand and protect these threatened regions and their species. Here I review the adaptive training programmes being implemented and developed by researchers at the Xishuangbanna Tropical Botanical Garden. These programmes last from four hours to six weeks, and all seek to address specific skills, in addition to building confidence and critical thinking. I review how syllabuses are designed and the types of exercises included to integrate and develop confidence and capacity in courses where the number of nationalities present may almost equal the number of participants. I provide evidence-based guidelines for the development, evaluation and evolving content of these courses, and provide examples of exercises that develop important non-academic skills for young conservationists.

Establishing a conservation ecology graduate programme: past experiences and future developments

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The past 15 years has seen an increase in the quality of Thai post graduate programmes focusing on wildlife ecology and conservation. The Conservation Ecology Program at King Mongkut's University of Technology Thonburi, Bangkok, started in 2004 by training graduate students in quantitative skills for both wildlife monitoring and ecology. The main practice that has increased the quality of the programme is requiring both MSc and PhD students to publish their thesis work in international peer-reviewed journals. This has increased their potential to successfully apply for future grants (e.g. PhD scholarships for MSc graduates) and become more competitive when applying for academic positions. Recently, the programme has started to link its activities with other Thai universities (e.g. Prince of Songkla University, Hat Yai) as well as regional universities (e.g. Royal University of Phnom Penh, Cambodia) by sharing courses and modules and co-advising students. In the long term, this close cooperation will become more important because, for the foreseeable future, no single programme has the depth or breadth to provide students with all the course work and training needed to make their curriculum complete.

Monitoring and combating forest threats through community participation

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Three Community Patrol Teams have been formed in two key areas of Seima Protection Forest—two in a Community Forest area that covers 9,070 ha, and one in Andong Kraloeng Village, which in 2012 was the first indigenous

community to receive collective land title in Cambodia. The community originally formed their own teams in response to rapidly increasing threats to their forest, but since October 2013 they have been supported by the Wildlife Conservation Society (WCS). Hundreds of hectares of land have been illegally cleared and settled by poor families from neighbouring provinces, and illegal logging has become a very serious problem in recent years. The galvanising issue for the communities has been the illegal felling of their resin trees, which are of vital importance to the livelihoods of local people. With support from WCS, the community patrol teams are now using Cyber Tracker-SMART enabled tablets to collect data and monitor both the patrols and emerging threats. Furthermore, the teams have received significant training from specialist law enforcement staff on patrol tactics, and SMART data are providing information for strategic deployment. Within 14 months the teams have made more than 64 arrests, and have confiscated 132 chainsaws, 64 modified motorcycles and 4 oxcarts. We present on the successes and challenges of Community Patrol Teams, and advocate for governments and NGOs to support local people, and to provide them the tools with which to protect their forests.

Reinventing the image of the king cobra *Ophiophagus hannah* as a flagship species for conservation education in rural Thailand

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Locally supported flagship species can serve as a rallying point for conservation activities. Reptiles, particularly snakes, are often viewed more negatively than other taxa, and are generally ignored for flagship consideration. Despite the fear snakes inspire, they may prove efficient flagships for conservation education as they are commonly found in human-dominated landscapes. The king cobra *Ophiophagus hannah*, the largest venomous snake in the world, is a flagship species candidate in Thailand due to its high profile, large home range, and its Vulnerable status on the IUCN Red List. Our work with Thai student groups found that the king cobra is the most feared snake, but hospital records for the area contained no king cobra hospitalisations. These results showcase the major gap between perception and reality, and the demand for educational outreach to reinvent the image of the king cobra. While radio-tracking king cobras in disturbed areas of Sakaerat Biosphere Reserve in northeastern Thailand, we have undertaken in situ conservation education, which has successfully changed how both king cobras and other venomous snake species are perceived by local communities. Many villagers have shifted from killing snakes to using our removal programme, which has led to the rescue of seven king cobras. Additionally, we have taught over 5,000 students from 58 different schools about king cobra ecology and conservation. King cobras show potential to anchor a conservation action plan that preserves intact areas and forest fragments within human-dominated landscapes by harnessing the support of local communities and students.

Reviewing six years of the “Program for Field Studies in Tropical Asia”

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Compared to tropical America and Africa, tropical Asia has far fewer field courses in ecology and conservation for graduate students and young researchers. Most notably the region lacks long-term programmes that provide continuous and standardised training. The Program for Field Studies in Tropical Asia (PFS) initiated in 2009 by Xishuangbanna Tropical Botanical Garden, Chinese Academy of Sciences, is the latest attempt to fill this gap and follows on from the earlier training courses run by the Centre for Tropical Forest Science–Arnold Arboretum Asia Program between 2001 and 2008. By running courses continuously, PFS aims to: (1) foster a regional network of young scientists; (2) improve research capability and confidence in young scientists from across the region; (3) provide a firm scientific grounding in addition to training in cutting-edge techniques in priority areas of research; and (4) build a regional consortium to inspire and educate young conservation biologists. We summarise PFS activities from 2009 to 2014, explaining the teaching philosophy and showing how the courses have evolved to meet the changing needs of students of the region, and then discuss how PFS intends to continue to grow and diversify into the future.

Saving Hainan Island's Yangshan landscape through citizen science

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In development projects, decision-makers and the general public tend to focus their conservation attention to remote natural ecosystems and flagship species, while countryside habitats and their associated wildlife are frequently ignored. The Yangshan landscape around the suburb of Hainan Island's capital city Haikou is one such example. The area consists of a mosaic of traditional villages beside lava rocks, woods, shrubs, seasonal agricultural fields and numerous spring-fed natural wetlands. The landscapes total area is approximately 300 km², with 8 km² of open water habitat. With recent Central Government designation of Hainan as an "international tourist destination", many infrastructure projects, especially real estate and golf courses, have commenced. Despite its close proximity to the city, little biological research has been conducted in the area, and many precious species could be destroyed before they are discovered and documented. To provide a scientific basis for better land-use planning of the area, we launched a citizen science project with support from the provincial conservation authority. A "Yangshan ecological investigation volunteer group" was formed by recruiting nature lovers from Haikou City. Under the guidance of specialists, the group spent their weekends and holidays collecting environmental and biotic data, aiming to highlight sites of special conservation value for enhanced protection. The findings were regularly communicated to relevant government agencies, as well as the public via social and press media, to raise awareness of the need to protect their own back garden.

To unlock the conservation deadlock? Use a blog

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Conservation practitioners foster positive changes in the environment, which to succeed, require understanding and support from the public. The rapid development of social media makes it possible to rapidly disseminate conservation messages in an easy-to-understand fashion. What makes the successful communication of a conservation message is the purpose of this work. Two-hundred and seventy Weibo posts (the Chinese version of Twitter) by Kadoorie Conservation China, a Hong Kong based team working on wildlife conservation in mainland China, were sampled and the readers responses analysed. Using the number of "read", "like", "comment" and "share", we gauged the level of public engagement in the published posts. Categories of posts that triggered the most responses were identified. Results indicated that Weibo posts that interest scientists and researchers might not be the same for the public, who were most responsive to conservation messages that were relevant to their daily lives and contexts they were familiar with. Photos and links to more detailed discussion of the messages resulted in more responses. Popular posts were well-crafted and sometimes, with one or more subjects being hashtagged. With increased knowledge of the users' behaviour, practitioners could utilise social media such as Weibo and Twitter to enhance communication of conservation messages. Although reaching a wider audience does not necessarily lead to behavioural changes, public understanding of the messages and responses could possibly translate into long-term changes and break the conservation deadlock caused by ignorance and indifference.

Understanding attitudes and usage of wild bear parts in Laos and Cambodia: a preliminary study using citizen scientists

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The illegal trade in wildlife is a leading threat to the continued existence of the Asiatic black bear *Ursus thibetanus* and sun bear *Helarctos malayanus*. Both species are in demand across Asia for their gall bladders and bile used in traditional medicine, and for their paws, claws and other parts used as delicacies or trinkets. In addition, wild cubs are taken for the pet trade or to supply bile farms. Despite synthetic and herbal alternative treatments being available, the demand for bear bile remains strong. The purchasing behaviour of consumers is a main driver

behind poaching and declining bear populations. Because attitudes often predict such behaviours, we developed a quantitative survey to better understand people's knowledge, attitudes, and beliefs towards bears and bear part usage in Lao PDR to inform the development of more effective conservation interventions. In addition, in Cambodia we are piloting the use of randomised response technique interviews to gather similar data. Lao citizen scientists administered the survey to 1,058 respondents. Self-reported use of bear parts among Lao respondents was lower (8.7%) than the perceived use among their peers (19.4%). While a fifth of Lao respondents believed that bear bile is effective medicine, our results showed a strong preference for wild bear bile over farmed bear bile. Lao responses differed significantly to western responses, indicating substantial differences in beliefs and attitudes. As such, conservation approaches developed in a western context may not resonate in Laos, underscoring the need for localised approaches to conservation.

Why biologists need to be non-biologists

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Despite the furious efforts of conservation biologists, non-biologists do not prioritise the environment. The problem lies in biologists not understanding non-biologists and what drives their decisions and behaviour. We exist in a capitalist society driven by non-environmental factors. National indicators are dominated by economic indices like the Gross Domestic Product or social indices like the Human Development Index. Employment sectors are dominated by agriculture, manufacturing and other businesses. Attendance at global conferences shows businesses and governments participating in environmental conferences, but few environment-related people attend economic, social and transport forums. The trend for collaborative conservation work with government, academia, NGO and private sector is increasing. If biologists want to influence non-biologists, we need to learn their language, comprehend why they make the decisions they do, empathise with their problems and understand how they view the environment. Only then we can better understand how to work together successfully. Topics like economics, sociology, education, urban planning, and marketing might be of interest, as would spending some time within the government, academic, NGO and private sectors.

Catering for diverse audiences in Lao PDR: how can we make conservation education and interpretation relevant? Is it even possible?

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Tat Kuang Si Park (TKS) is one of the most popular tourist attractions in Lao PDR, attracting over 200,000 local and international visitors every year. Home to one of the region's most stunning waterfalls, as well as an impressive 30 m+ forest canopy and Laos' only dedicated sanctuary for rescued bears, TKS offers a rare opportunity to engage a diverse audience in environmental issues as part of a recreational day out. Development of a new interpretation experience The Forest & Wildlife Discovery Trail has been underway since mid-2013, aiming to provide visitors to TKS with an improved understanding of the importance of protecting Laos' natural environment. The development of the trail draws heavily on the work of Professor Sam Ham, following Ham's principles of Thematic, Organised, Relevant and Enjoyable Interpretation. The challenge at TKS was to develop signage that met all criteria for such a diverse audience. The new trail was developed through a consultative process, understanding local social norms and behaviour change theory while taking into account perceived Asian values based on observations and informal interviews with visitors to TKS. Additional input was sought from Lao colleagues, tour guides and other contributors with experience in Southeast Asian conservation. Future work to measure and evaluate the impact of this trail will help guide subsequent developments and ensure that visitors enjoy themselves on a day out at TKS, but also leave feeling inspired to ensure future generations can continue to enjoy the rich biodiversity of Laos for years to come.

Symposium—Continued conflict or co-existence: human impacts on primate behaviour and ecology

Can non-territorial animals range and behave like territorial ones when food provisioned?

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Human food is a hypercaloric resource that can be a diet supplement for animals living close to humans. Because human food is usually clustered, animals may reduce their travel distances and home ranges, or even alter their territorial behaviour, given the economic defensibility of such a food arrangement. We compared the ranging patterns of a group of northern pigtailed macaques *Macaca leonina*—a typical non-territorial primate species—that was strongly dependent on human food, with a wild-feeding group. We also compared the macaques' movements with those of a group of white-handed gibbons *Hylobates lar*, a territorial species inhabiting the same site. Home ranges, core areas and daily path lengths were significantly smaller for the semi-provisioned macaques than for the wild-feeding macaques. In addition, the relation of daily path length and home range size of the semi-provisioned group resulted in a defensibility index that theoretically corresponded to that of territorial species like gibbons. The wild-feeding group showed little fidelity to either a home range or a core area, whereas the semi-provisioned group exhibited stronger fidelity to both area types, as gibbons did. The semi-provisioned macaques presented several agonistic intergroup encounters compared to the wild-feeding group. These findings indicate that high-energy food concentrated in defensible spots produced territorial traits in the macaques' ranging patterns and intergroup behaviour. This modification in ranging dynamics may decrease the efficiency of macaques as seed dispersers, increase their predation impact on their home range, and thus generate important consequences for plant regeneration and animal diversity.

Community-based ecotourism (CBET) as a tool for sustainable natural resources use and livelihood improvement

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Ecotourism is growing rapidly in Cambodia due to its potential for improving both wildlife conservation and the livelihoods of local people. While many studies show the negative effects of tourism, this paper presents a challenging, yet successful example of primate based ecotourism at Veun Sai–Siem Pang Conservation Area (VSSPCA) in Ratanakiri Province. This is located approximately 588 km from Phnom Penh and is a 55,000 ha area of lowland evergreen forest that borders Virachey National Park. The forest has high biodiversity value, being home to eight of the 16 most threatened terrestrial species in Cambodia and the largest known global population of northern yellow-cheeked gibbons. Although it is rich in natural resources, Veun Sai has seen an increase in illegal activities (logging and hunting). In an attempt to combat this Conservation International prioritised the development of a community-based ecotourism project (CBET) for gibbon viewing. Over the five years of the CBET project there have been many challenges, including the fact tourism jobs compete with illegal logging for a source of income. Despite this, we have seen a steady increase in the number of tourists that visit every year and tourism revenues used for bridge and school construction and provisioning of no interest loans for locals to run small businesses. Most importantly, we have shown that CBET members can make more money from tourism than logging, which has changed the mindset of many villagers who now want to protect the gibbons.

Conservation status of pygmy slow loris *Nycticebus pygmaeus*, Bonhote, 1907 in eastern Cambodia

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Pygmy slow loris *Nycticebus pygmaeus* carcasses have been frequently reported since the 1990s, and recent large-scale deforestation has occurred within the species' distributional range. It is listed as Vulnerable in the IUCN Red List and on Appendix I of CITES, based on increasing and unsustainable trade, habitat loss and degradation. Founding work in Cambodia identified very low densities of pygmy slow lorises in many sites in eastern Cambodia and attributed this to intensive hunting pressure. In 2009, preliminary surveys identified high loris abundance indices within Veun Sai–Siem Pang Conservation Area (VSSPCA), Northeast Cambodia. Following these surveys, an integrated conservation and development project was implemented by Conservation International in VSSPCA. Local communities signed conservation agreements, which included a hunting ban of this species in exchange for training and livelihoods improvement. We repeated the sampling in 2009 to determine the success of the agreement. Initial survey data suggests a local population decline of this species. The pygmy loris is highly prized for medicinal use and interviews within the community with local people also suggested that hunting effort did not decline, despite conservation agreements. We examine why conservation agreements were insufficient to halt declines of this species, and what actions may now be required to conserve the pygmy lorises of eastern Cambodia. Without effective conservation action, local extirpation of this species is likely.

Feeding monkeys and losing trees: consequences of provisioning rhesus macaques for seed dispersal

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Provisioning wild primates is a socio-religious tradition in many Asian countries, including India. However, such anthropogenic supplemental feeding brings about enormous changes in primate demography, behaviour and ecology and is seen as one of the main drivers of human–primate conflicts in urban and rural areas. Little attention though has been paid to the ecological impacts of primate provisioning. We conducted a study on the feeding ecology of rhesus macaques *Macaca mulatta* to investigate the consequences of provisioning on their role as seed dispersers. Rhesus macaques are widely distributed across much of Asia and inhabit a variety of habitats from forests to urban cities. From September, 2013 to August, 2014, we collected behavioural and phenological data on a semi-provisioned troop of rhesus macaques in the Buxa Tiger Reserve, India. Our results show that provisioning negatively affects the seed dispersal abilities of rhesus macaques. Irrespective of fruit availability, frugivory in the macaques declined with increasing degree of provisioning. Seed dispersal by defecation or expectoration also decreased during provisioning periods. In addition, macaque daily ranges decreased during provisioning, resulting in shorter dispersal distances. Finally, during provisioning periods, macaque-handled seeds were usually deposited on tarmac roads, thereby precluding seed germination. Primates and plants interact in very complex ways that are not fully understood yet. Primates depend on plants for food resources, while plants rely on frugivorous primates for seed dispersal. Our study underscores that human activities that affect any aspect of this interface, even in a limited fashion, critically impact the health of ecosystems.

Impacts of logging on ranging patterns of silvered langurs in northeastern Cambodia

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The Annamese silvered langur *Trachypithecus margarita* is an Endangered colobine found in certain locations of Cambodia, Vietnam and Laos where, as in the rest of the Indo-Burma biodiversity hotspot, populations of primates are increasingly at risk from human pressure. Illegal logging for precious hardwoods is a very widespread human activity in Cambodian protected areas, with potentially serious effects on their biodiversity and ecology, as well

as the economy of the country. This study aimed to document the effects of logging activities on the ranges and habitat use of Annamese silvered langurs in a Cambodian conservation area. Data were obtained from April 2013 until May 2014 by registering daily ranging behaviour and canopy use of an unhabituated group of langurs in Veun Sai-Siem Pang Conservation Area, Ratanakiri Province, Cambodia, where logging activities were rampant during 2013. We also collected data on logged stems, daily number of chainsaws, location and length of logging episodes in the group home range. We found that some areas in the home range were completely abandoned by the group after heavy logging was carried out, and that both number of chainsaws and logging length greatly influenced the group, making it spend significantly more time in the upper layers of the canopy. These results show that logging activities have a great impact on the way the species moves and uses its environment, and that langurs will at least avoid areas where logging is frequent and intense.

The ecology of the Endangered yellow-cheeked crested gibbon in areas of high human presence: implications for long-term conservation

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There is scarce information about the habitat requirements of yellow-cheeked crested gibbons *Nomascus gabriellae* in the Seima Protected Forest (SPF). This study aimed to estimate the home range size of one focal group of semi-habituated *N. gabriellae* and assess habitat characteristics both within the home range and in adjacent habitat. Data were collected in SPF from February to April 2014. Point locations were collected and a kernel estimator was used to estimate the group's home range, and a systematic grid of 91 plots was used to assess the habitat characteristics of two areas. Three home range contours were estimated: 50% contour (14.9 ha), 85% contour (38.6 ha) and 95% contour (57.8 ha). Three habitat characteristics showed no significant difference between two areas; however, two other characteristics showed a significant difference. The home range analysis suggested that the focal group's area of utilisation overlaps with some areas of the Indigenous Communal Land Title (ICT) of Andong Kraloeng Village, as this community land is still forested. This study has highlighted some key habitat characteristics that may be selected for by *N. gabriellae*, which has implications for law enforcement in the context of increasing threats such as selective logging and land clearance. The existence of the ICT within the group's home range demonstrates the challenges of long-term conservation in protected areas with a large human presence. We discuss the potential solutions in light of a primate-focused, community-based ecotourism project in the area, and the challenges of effective management under increasing threats.

The importance of large trees to gibbon seed dispersal

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Seed dispersal patterns generated by dispersers are important because they are considered to be the template from which plants recruit. The spatial patterning of the seed rain is often highly influenced by disperser behaviour. Vertebrate dispersers that congregate in specific locations for long periods of time often disperse seeds in aggregations. These aggregations of seeds can influence patterns of recruitment that are important for species sorting, community composition and species coexistence. Gibbons, especially those in the genus *Nomascus*, are excellent models for studying how aggregated seed dispersal may influence seedling recruitment because they disperse a large proportion of seeds beneath the trees in which they sing every morning. Here, we tested the hypothesis that northern yellow-cheeked gibbons *Nomascus annamensis* create "hotspots" of seedling recruitment beneath their singing trees. To do so, we compared species composition and number of seedlings and saplings in plots beneath gibbon singing trees and in randomly-placed plots not under singing trees. We found that plant species known to be dispersed by gibbons were at significantly higher densities beneath gibbon singing trees. Gibbons specifically select tall emergent trees in which to sing, sleep and rest. As these types of trees are increasingly being sought for selective logging, our study indicates that not only are these large trees critical to gibbons, but their presence may be important for community composition and species diversity.

Tree use by northern yellow-cheeked crested gibbons *Nomascus annamensis* in northeastern Cambodia: implications for gibbon conservation

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This study examined the sleeping and calling tree use of one habituated group of northern yellow-cheeked crested gibbons *Nomascus annamensis* in Veun-Sai Siem Pang Conservation Area, Cambodia to determine if these gibbons follow the same selective strategies of other species of Hylobatidae. The location of sleeping and calling trees were recorded and measurements taken of tree characteristics including species, height, diameter at breast height, presence of lianas and patterns of re-use. We identified 50 sleeping trees and 171 calling trees in which 38 and 69 were measured, respectively. The gibbons selected 11 tree species for sleeping and 17 tree species for calling. They most frequently slept in (58%) and called from (64%) only three tree species (*Dipterocarpus costatus*, *Shorea thorelii*, *Anisoptera costata*) that are all listed as Endangered or Critically Endangered by the IUCN. The gibbons selected tall, often emergent, sleeping and calling trees that were significantly taller and larger in diameter than adjacent trees. The majority of sleeping trees had lianas (53%) and were rarely re-used (12%). This study demonstrates that *N. annamensis* follows the same selective strategies as other gibbon species and confirms the high degree of selective preference for dipterocarps as sleeping and calling trees. Dipterocarps are still relatively abundant in Cambodia, yet also have high commercial value. Thus, our study suggests that to maintain gibbon habitat they should be a target for conservation initiatives.

Least Concern cause for much concern? The impact of human–macaque conflict on bonnet macaque conservation status

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Human–primate conflict due to crop-raiding involves many primates in India. Chief among these are the rhesus macaque in northern India, the bonnet macaque in southern India and the Hanuman langur across India. Although there are a few studies regarding human–rhesus conflict and Hanuman langur–human conflict, little is known about bonnet macaque–human conflict. We initiated a study in Kerala, southern India, to investigate the pervasiveness of the issue in the state and its impact on bonnet macaque conservation status. Results from a questionnaire survey conducted in a high-conflict region in Kerala indicate that macaque conflict has increased dramatically in recent years and that farmers deeply resent the presence of macaques in their area. Both wild pigs and macaques are major crop raiders, but farmers were particularly bitter about macaque activities because they could not retaliate against the macaques. Macaque translocation and culling is a common response to macaque crop-raiding activities in many areas across India. The latter measure is a very real danger in Kerala, where government laws now permit farmers to shoot crop-raiding wild boar individuals. Due to its commensality and common presence in human settlements, the bonnet macaque is categorised as Least Concern on the IUCN Red List. However recent demographic studies on the bonnet macaque indicate that populations have declined and that the species has disappeared from many regions where it was found previously. We recommend the urgent need for strong intervention measures, before the bonnet macaque completely disappears from our midst.

Wild-to-wild translocation of limestone langurs: a case study of *Trachypithecus poliocephalus* on Cat Ba Island, Vietnam

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With a global population currently consisting of approximately 65 individuals limited to the small island of Cat Ba in Northern Vietnam, the Cat Ba langur *Trachypithecus poliocephalus*, is one of the world's most endangered primates. By 2000, hunting pressure had reduced the numbers from an estimated 2,500–2,700 in the 1960s to near

extinction levels. Natural recovery has been hindered by an extremely fragmented population with some isolated sub-populations consisting of non-breeding, all-female-groups. Active population management to consolidate the population was considered necessary and translocation of the all-female groups was deemed the most viable option. In 2012, after nearly 10 years of planning, the Cat Ba Langur Conservation Project successfully conducted the first wild-to-wild translocation of a limestone langur species. The translocation involved capturing two females isolated in the northern portion of the island, followed by transport to, and release into, the largest breeding population on Cat Ba Island. The translocation demonstrated the feasibility of wild-to-wild translocations and that introduced animals can be smoothly integrated into an established population. This translocation also demonstrated the importance and effectiveness of using local knowledge for conservation purposes.

Do males care? Patterns and consequences of male-immature association in a wild promiscuous primate

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Male infant care is generally not expected in promiscuous mammals. Recent evidence from non-human primates, however, indicates not only the existence of stable male-immature associations in multi-male, multi-female groups, but also male care in form of protection from infanticidal attacks and harassment by conspecifics. Here, we investigate characteristics, dynamics and consequences of immature-male associations in wild Assamese macaques *Macaca assamensis*, to inform hypotheses about adaptive values for immature individuals. Male-immature associations are predicted by paternity despite low mating and paternity skew, thus immature animals may benefit from paternal care. Here, we present focal animal data on 12 immature animals followed from birth into their juvenile life. The distribution of composite sociality index values suggests that male-immature relationships were highly differentiated. Association patterns and the degree of differentiation remained stable from birth well into the juvenile phase and, based on Hinde indices, immature individuals were responsible for maintaining their relationships to adult males. The likelihood that an immature individual was associated with its preferred male partner increased if its mother was absent and other males were within less than 5 m, suggesting that immature animals sought protection. The presence of the preferred male did not decrease the rate of mild aggression immature individuals received from group members, though, and preferred males did not support immature partners more often than other group members did. Together with previous studies, these results suggest that differentiated, stable immature-male associations may decrease risk of lethal aggression from conspecifics and benefit immature individuals long-term via enhanced resource acquisition, undisturbed feeding and potential agonistic support against competing juveniles.

Long-term monitoring of siamang in Bukit Barisan Selatan National Park: 17 years after ENSO-related wildfires

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The El Niño Southern Oscillation (ENSO) event in 1997 led to catastrophic fires across Indonesia. This study focuses on the impact of wildfires associated with the 1997 ENSO event on the siamang *Symphalangus syndactylus* population in a Sumatran tropical forest. The aims were to assess the dynamics and persistence of siamangs and to compare the demographic characteristics of groups in burnt areas and areas untouched by the ENSO fires. Previous research has suggested that four years after the fires, siamang groups in previously burnt areas had a smaller group size, smaller home range, contained fewer non-adult individuals, and had a lower infant survival rate than groups in area not affected by fires. Annual censuses were conducted every year from 1997 to 2014 to monitor siamang populations in a 165 hectare area that was burnt in 1997 and 635 hectare unburnt control areas. Results indicate that by 2004 (seven years after the ENSO event), there were no significant differences between groups in burnt and normal area in terms of group size and group structure. This indicates that in large and undisturbed forested landscapes, the impact of large fire events on siamang populations is relatively limited, and siamang populations are able to recover if burnt areas are allowed to regenerate.

Symposium—Achieving emission reductions under each element of the REDD+ scheme

Forest restoration for carbon stock enhancement under REDD+: the potential of natural regeneration

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This study assessed the potential for assisted natural regeneration (ANR) to enhance carbon stock accumulation on a former dry dipterocarp forest site in Kampot Province, Cambodia. Initial regenerant density (all trees and live tree stumps taller than 50 cm) averaged 6,750/ha across the whole site, with patchy canopy closure. ANR plots were protected from fire and subjected to weeding and vine-cutting three times during one growing season. Biomass data and soil samples were collected from 10 circular sample plots (40 m²) in the ANR treatment area and 10 plots in an adjacent control area, without a firebreak, both before and after ANR treatments. Regenerant density increased significantly ($P < 0.001$) in both ANR and control plots (+76% and +58% respectively), but final differences in regenerant density remained insignificant ($P = 0.307$). Regenerant species richness increased similarly in both the ANR (+12 species, 30%) and control (+11 species, 33%) plots. Carbon storage also increased significantly from 30.21 to 56.79 tC/ha (+88.0%) in the ANR plots and from 29.54 to 50.28 tC/ha (+70.2%) in the control plots, predicting a return to values typical of more mature deciduous dipterocarp forest within a few years. However, final differences in carbon levels were insignificant between ANR and control plots, suggesting that the ANR treatments applied in this case did not accelerate carbon accumulation above natural levels. We conclude that natural regeneration can accumulate significant carbon stocks in dry forests in Cambodia, but that in this particular study, the ANR treatments did not accelerate carbon accumulation beyond natural rates within a single growing season. Since regeneration was advanced, the regenerants were probably not inhibited by weed competition and were therefore unresponsive to weeding and vine-cutting.

Implementing REDD+ in the Seima Protection Forest, Cambodia

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Carbon sequestration in high conservation value forests has the potential to be a potent force in climate change mitigation and biodiversity conservation, providing sustainable financing and offsetting the economic drivers of deforestation. Avoided deforestation must be part of any global agreement, in particular in developing countries with rapid land-use change, where deforestation can be the dominant source of emissions. The Royal Government of Cambodia, with technical and financial support from a range of partners, is implementing a REDD+ readiness process, including work at demonstration sites. REDD+ development in Cambodia faces similar challenges to other countries, with complex tenure issues, high transaction costs, and low market demand. While project development is making steady progress, and readiness and capacity building efforts have relatively good support, no significant performance-based transactions have been made, and the resources to compete with drivers of deforestation remain very limited. Expectations from REDD+ are high: decision-makers, government agencies, donors, and especially local communities, risk becoming disillusioned if progress remains slow. Furthermore, high rates of planned deforestation outside of project areas, and widespread external threats to land and forest, may undermine public confidence in REDD+. We describe a case study from the Seima Protection Forest, a national demonstration site, where recognition of traditional forest user rights and support for indigenous communal land titles is part of the government's forest co-management strategy.

Local community perspectives on REDD+ benefit sharing: a case study from a REDD+ demonstration project in Cambodia

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REDD+ offers potential financial incentives to reduce emissions from deforestation and forest degradation in developing countries. How these financial incentives should be distributed among stakeholders, especially at local levels, has recently been discussed broadly at an international and national level. However, few studies have examined how local communities at a REDD+ demonstration site propose that financial benefits from REDD+ should be distributed. Based on qualitative methods conducted at one such site in Cambodia, Seima Protection Forest, this study found that REDD+ benefit-sharing had yet to be comprehensively discussed. Local communities have, however, proposed that revenue from REDD+ should be used to support forest protection through patrols and community meetings to raise awareness in the area. Remaining REDD+ revenues should be used for infrastructure development (e.g. health care centres, schools and roads) and literacy training in local communities. Finally, livelihood improvement projects for local communities, such as development of agricultural techniques, ecotourism and livestock-raising, have yet to be considered. In conclusion, local communities in Seima Protection Forest expect revenues from REDD+ to support their forest protection efforts and contribute to enhancing their livelihoods.

OTHER SYMPOSIA

Plants and system dynamics

At what level is recent fragmentation detectable in landscapes?

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Within landscapes, plants group into communities of co-occurring species reflecting trade-offs across abiotic and biotic gradients. These communities may differ in their susceptibility to human activities, which, if evaluated at landscape level may not be detectable because of compositional differences between communities. Here, we evaluate whether the effects of recent fragmentation (<25 years) on herbaceous community assemblage in the tropical forests of Xishuangbanna, China, can be detected across the landscape or only within forest communities. We sampled understorey herbaceous vegetation in a previously established forest fragment plots, where three forest communities was identified – Mixed, Oak, and Limestone – and collected 27 environmental variables in each plot describing abiotic, biotic and anthropogenic effect properties. First, we established whether herb composition coincided with the identified forest communities using NMDS ordination. We then used multiple regression analysis to determine which environmental variables drive herb composition, density and richness across landscape and within forest communities. Our results confirmed that there were distinct herb communities that coincided with the three forest types, with variable environmental predictors explicit to these communities. We only detected the effect of fragmentation within forest communities and not across the entire landscape: effects were detected for Mixed and Oak forest but not for Limestone forest, implying the vulnerability of accessible communities to human disturbance even in a short time. Analysis of the unique communities within a landscape can elucidate the effects of land-use conversion in this diverse but overexploited region and direct management towards threatened communities.

Leaf litterfall, nutrient return and decomposition across a tropical forest disturbance gradient

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Anthropogenic activities are the principle drivers of deforestation and forest degradation, resulting biodiversity loss and also alter ecosystem functioning through changes in species composition and abiotic conditions. However, the consequences of these changes on ecosystem processes, such as litterfall and decomposition, are often poorly understood. To overcome this knowledge gap, litterfall and decomposition experiments were conducted along a tropical montane disturbance gradient from mature forest to open grassland and tea plantations in Southwest China. We measured the effect of forest disturbance on litterfall and nutrient quality through litter traps and quantified the effects of litter quality, litter fauna and seasonal precipitation regime on litter decomposition through a litter-bag experiment (3,360 bags). Total litterfall decreased from forest habitats to tea plantations. However, there was no significant effect of disturbance on litter nutrient concentrations, even though the habitats had quite distinct plant species composition. Across the landscape, mass loss from litter-bags after 12 months varied from 7–98%. Decomposition rates declined substantially along the disturbance gradient from mature forest to open land, although the effect size was strongly dependent on installation season. The effect of faunal exclusion increased substantially with increasing forest degradation, whereas the litter quality effect declined. To better model the impacts of anthropogenic global change on litterfall and decomposition rates, it will be important to consider landscape scale processes, such as forest degradation.

Litter production in rubber agroforestry and rubber plantation, southern Thailand

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Litter production represents the litter dynamics that govern nutrient supply for system. This study compared litter production in rubber agroforests and rubber plantations in southern Thailand. The experiment was conducted in three pairs of rubber agroforests and rubber plantations in Songkhla and Trang provinces by randomly setting 15 litter traps in each plantation. Dry weights of litterfall were measured every month from January to December 2013. The mean annual litter production of the rubber agroforests was higher than that of rubber plantations (0.33 Mg/ha/yr and 0.20 Mg/ha/yr, respectively). Leaf litter contributed about 60% of total litter production. Litter production had its highest peak during the dry season (March–April). These results suggest that rubber agroforestry is better than monoculture rubber plantations at increasing nutrient inputs in an agricultural ecosystem.

Temporal changes in tree species and trait composition in a typhoon-prone Pacific dipterocarp forest

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Our understanding of the effects of tropical cyclones on species composition and dynamics of forest communities are derived from studies that considered single cyclonic events. However, some studies suggest that cyclones may increase in both intensity and frequency under climate change, making studies that can provide information on their combined impacts on forests necessary. We examined the changes in tree species composition and traits in a 16-hectare lowland dipterocarp forest in the northeastern Philippines within the path of 1–4 typhoons annually. Across the whole study period (1994–2010), species and trait composition moved away from the initial 1994 configuration, with a significant shift towards an increased abundance of species with faster growth,

lighter wood, lower leaf water content, and increased photosynthetic activity—traits that are associated with fast recovery after disturbance. The changes over shorter time periods (3–6 years) were more dynamic, and reflect the cyclone occurrences within the same time frames. This study provides insights on the compounded effects of multiple disturbances and the overlapping processes of damage and recovery.

Ants and their role in forest transformation systems such as rubber and oil palm plantations

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Land-use change causes undesirable effects such as biodiversity decline, altered community structure and reduced ecosystem services. Changes in species composition and disrupted trophic interactions between pests and their natural enemies may indicate decreasing ecosystem services. This research was conducted to study the effects of forest habitat transformation on the community structure of ants, which include major biological control agents. We focused on four types of land use, i.e. forest, jungle/rubber, rubber plantation and oil palm plantation, around Harapan Forest (Harapan) and Bukit Duabelas National Park (BDNP), Jambi, Indonesia. To study the effects of tree age, oil palm plantations of different ages were selected. Ants were collected using hand-collecting, baiting and exposing pitfall traps on each of a total of 32 plots. Our results showed that the total number of ant species per plot did not differ significantly between land-use types around in Harapan and BDNP, but ant species composition differed significantly among land-use types. We conclude that conversion of remnant forest to plantations would result in a net loss of certain ant species, even when ant species richness in plantations and forested habitats are similar.

Natural enemies in oil palm plantations: their role and utilisation

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The increasing world demand for palm oil is causing massive conversion of forest and agricultural land to oil palm plantations. As a consequence, biotic homogenisation is emerging in the form of oil palm monocultures that can potentially lead to unbalanced ecosystem functioning and the emergence of pest outbreaks. Natural enemies in oil palm plantations typically cannot control pest populations due to unsuitable habitats. The aims of this research were: (i) to study the presence of natural enemies in oil palm plantations; and (ii) to study the potential role of natural enemies for controlling pest outbreaks. The diversity of both predators and parasitoids was observed using direct screening of oil palms, trapping (pitfall, yellow pan and malaise), baiting and host collection. Different ages of oil palms as well as habitat condition were considered in this research. The effectiveness of parasitoids and predators was investigated through the study of their spatial occurrence on selected plots followed by predation experiments in the laboratory. Our results showed that predators and parasitoids were always present in oil palm plantations, independent of age and habitat condition. Some predators, especially ants, were found to be abundant in several plots. Nevertheless, they could not effectively control pest populations especially Lepidoptera, because of the limited carrying capacity of natural enemies in homogenous habitats. Predation experiments also showed that ants were ineffective in controlling pests, especially caterpillars. Modifying habitat conditions may be a promising option to increase the abilities of natural enemies to control pests in oil palm plantations. Further research is needed to develop a strategy to better utilise natural enemies for biocontrol in oil palm plantations.

Other fauna

Constructing a species distribution map for rare seahorses using anecdotal information and in-water surveys

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Seahorses are heavily traded on the global wildlife, market mainly for traditional Chinese medicine. According to official records, Vietnam ranks among the top 10 exporters of seahorses worldwide. Basic biological information is needed to manage seahorse trade and assess the status of wild populations. However, seahorses are rare, cryptic and patchily distributed, and thus data-poor. Through this project, seahorse distribution and habitat preferences were documented to inform conservation and management. Underwater surveys were conducted off the central and south coasts of Vietnam in 23 sites. Because seahorses are not always detected through in-water surveys, 57 fishers and other local stakeholders were interviewed to determine seahorse occurrence, species caught, seahorse habitats and catch rates. Seahorses were scarce in the survey, and were found in only five sites around Whale Island and the island of Phu Quoc. Along the coast, seahorses were commonly caught in bottom trawls, and many fishers estimated that seahorse populations have declined over the past decade. The commonest species from surveys and in landings made by fishers was *Hippocampus spinosissimus*. Four species—*H. spinosissimus*, *H. trimaculatus*, *H. kuda* and *H. mohnikei*—were all found in soft-bottom habitats, such as silt, sand and seagrass. *Hippocampus kelloggi* and *H. histrix* were found in deeper waters, and were usually caught by trawlers operating far offshore. Our findings indicate immediate action is needed to protect seahorses and their habitats, especially around Phu Quoc, which hosted the highest abundance of seahorses in our surveys, but where fishing pressure was also intense.

Foraging patterns and flocking of sympatric hornbills during the non-breeding season

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The study was conducted in Khao Yai National Park, Thailand, where close sympatry is observed between four hornbill species, namely: great hornbills *Buceros bicornis*, wreathed hornbills *Aceros undulatus*, Oriental pied hornbills *Anthracoceros albirostris* and white-throated brown hornbills *Anorrhinus austeni*. The morphology and chemical components of fruits eaten or not eaten by hornbills were studied during the non-breeding season. Figs were an important species in the diet during the entire year. Flocking was observed from the end of June, immediately after the end of the breeding season, until the end of December, just before the start of the next breeding season. During both non-breeding seasons, a total of observation time of 680 days over 12 months was spent counting the maximum number of individuals in flocks at roost sites. Among these four species, great and wreathed hornbills seemed to have the most regular pattern of flocking. However, no regular roost site was found for the white-throated brown hornbills. White-throated brown hornbills were found to live in small flocks of 8–54 individuals (33.5 ± 15.5 , $n = 20$). We identified their Food Abundance Index (FAI), and found that total FAI varied, particularly in the non-breeding season. The number of fruiting species did not influence total FAI. On average, the abundance of hornbill food fruits was comparatively high, at about 50% of the total fruiting trees. There was no significant correlation between the FAI of the fruit foods of each hornbill species and their flock sizes.

Observations of the domestic bushmeat trade in markets in Lao PDR

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In Lao PDR, illegal domestic and international wildlife trade is common and represents a significant threat to national and international wildlife. From 2010 to 2013, surveys of wildlife markets and roadside markets and stalls were conducted by WCS across Laos to assess the conditions and volume of domestic bushmeat trade. Observations of wildlife vendors were made to record the species, condition of the animals (live, dead, parts), volume, and prices. Information on price and weight were obtained by standing near the wildlife vendors and listening to their conversations with customers. Surveys were conducted in 93 markets, including roadside markets or stalls, where wildlife were openly traded. In a total of 376 visits, 33,759 carcasses from 185 wildlife species were observed for sale. This represented an estimated total biomass of 15,855 kg. Of the 93 survey sites, 11 markets or roadside markets were identified as wildlife trade hotspots, where more than 100 animals per day were found on at least two visits. A varied mixture of mammals, birds and reptiles were observed in markets and more than half ($n = 17,756$) of individuals were wild birds. On an average day at a typical market, a visitor would likely see rodents, ungulates, carnivores, wild birds, bats (if near limestone karsts) and lizards (in the south of Laos). Wildlife was most commonly sold as whole fresh dead animals, but live animals were also common. Freshly dead wildlife was consistently more expensive than the equivalent amount of fresh domestic pork. Of the 33,759 carcasses, 6,459 (19%) were observed to be species listed by the Lao PDR Wildlife and Aquatic Law as being rare or near extinct (Category I) or species that will become extinct if management is neglected (Category II). Our data show the high magnitude of the domestic bushmeat trade in Laos. Trade has already led to the significant declines of wildlife populations in Laos and will continue to do so if the trade is not controlled. In addition, the bushmeat trade represents a threat to human health, due to an estimated 72% of emerging zoonotic diseases originating in wildlife. A multi-sector approach is needed to effectively address wildlife trade to protect biodiversity and public health.

Amphibian responses in human modified landscape at Gianyar Regency Bali

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Landscape modification affects amphibian communities and creates specialist and generalist species. This research aimed to observe the response of amphibian communities along a gradient of human modified landscapes (settlements, rice fields, non-irrigated agricultural fields, and monoculture stands) in Gianyar Regency. Observations were carried out in July–October 2014 using standard visual encounter surveys. The body condition of generalist species was also assessed. Eleven amphibian species ($n = 751$ individuals), representing four families, were found. The amphibians observed were dominated by *Duttaphrynus melanostictus* (31.8%), *Microhylla palmipes* (21.84%), and *Fejervarya limnocharis* (17.84%). There were three main habitats for amphibian communities: settlements/non-irrigated agricultural fields, monoculture stands and rice fields. Non-aquatic species had the highest diversity in monoculture stands (Shannon-Wiener index $H' = 1.12$), and lowest diversity in residential areas ($H' = 0.31$). The diversity of amphibians increased when: (1) close to water sources; (2) vegetation cover increased; and (3) the anthropogenic disturbance factor decreased. *Occidozyga lima*, a specialist species, was only found in specific habitats (rice fields), while *D. melanostictus*, a generalist species, was encountered at a high rate in all habitat types. The body condition of the generalist species (*D. melanostictus*) showed that landscape modifications resulted in an increase in abundance but a decrease in body size.

Horses in the Orient—a seahorse population survey off Penang Island, Malaysia

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In Southeast Asia, seahorses (*Hippocampus* spp.) are traded mainly for traditional Chinese medicine and to a lesser extent as curios and ornamental fish. Because seahorses have low mobility and low fecundity, they are prone to overexploitation, especially as they are mainly caught as bycatch. Population assessments have not been carried out widely in Malaysia despite being host to 13 species. This research aimed to identify seahorse hotspots in Penang National Park through underwater visual surveys and to determine seahorse species diversity, distribution and relative abundance in the waters off Penang Island through port sampling and fisher interviews. Port sampling involved examining the dried seahorse collections of fishermen and recording live landings of seahorses over six months. Fishers were interviewed at ports to determine seahorse catch sizes, identify seahorse hotspots and potential threats. All seahorse individuals observed were identified to species, sexed and measured. In Penang National Park, we confirmed the presence of 10 individuals from two species—*H. comes* and *H. kuda*—while 175 individuals from four species—*H. trimaculatus*, *H. kuda*, *H. comes* and *H. mohnikei*—were recorded from port sampling. *Hippocampus trimaculatus* was the commonest species and the most widely distributed in Penang waters. Although seahorse bycatch rates differed according to port locality, fishermen noted an overall decrease in seahorse catch compared to a decade ago, citing coastal development and trawler encroachment as main factors. Our findings indicate that marine areas in Penang are important habitats for seahorses. Urgent fishery management actions are needed to prevent further population declines.

Miscellaneous

Tapping the free and unlimited energy of the sun for biodiversity conservation: case study of a “proof-of-concept” project

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Habitat destruction in the uplands, including deforestation, land clearing and cultivation, is a major driver of biodiversity loss in the Philippines. Poverty and high population growth have led people to migrate to the uplands and destroy the habitats of forests and native flora and fauna in their attempts to gain a livelihood by engaging in illegal logging, producing firewood and charcoal, and cultivating the land for growing various crops. To obviate this situation and prevent biodiversity loss, the proposed answer is the provision of an appropriate alternative sustainable livelihood. In this proposed production system, its foundational basis is the daily exploitation of the free and unlimited energy of the sun for photosynthesis by plants/trees that grow anywhere or that can grow on marginal lands, roadsides, and unused lands: they do not require fertiliser and pesticide inputs, and they are not susceptible to harvest failure due to the vagaries of climate change. Their daily production of leaf biomass can support the next trophic level. To provide evidence that this concept will provide sustainable livelihood that will at the same time conserve the environment and prevent biodiversity loss, I initiated a community-based research cum development project that I personally funded—a model prototype of a production system that I will call “native goat farming in a cut and carry system for daily milk production and daily income generation”. The project started in July 2011 and provided one female goat to each of 40 household beneficiaries/co-operators with the vision that this would be multiplied to a sufficient number of female goats that could be milked daily and would be of sufficient quantity not only for household use but for income generation. In return for the female goat, every co-operator is required to return a female kid which, to increase the number of co-operators, could be given to a new interested co-operator or to a co-operator whose goat had died. This paper will elaborate on the project (which is expected to continue and be monitored over the author’s lifetime) by describing the events and

progress towards the vision of the project during the three and a half years that have elapsed since it started (now totalling 69 goats), lessons learned, future expectations, and recommendations.

New species of Perlidae (Insecta, Plecoptera) in the Philippines: characterisation and its molecular evidence in associating life stages

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Improved taxonomy of freshwater invertebrates provides a better understanding and offers a more effective bioassessment of aquatic ecosystems. Stoneflies (Plecoptera) have long been used as indicators for water quality, but a long-standing constraint of using these aquatic macro-invertebrates for riparian environmental assessments is the difficulty of identifying species, particularly in the immature stages. The study aimed to identify the stonefly species in Layawan riparian system, Mount Malindang, Philippines. We used genital and egg morphology to identify adults to species, geometric morphometrics in determining the body shape variation of nymphs, and associated DNA barcoding sequences of both life stages to evaluate the diversity of stoneflies. Two new species of adult *Neoperla* and one species of *Phanoperla* were identified. The male of *Neoperla* species A had a longer aedeagus bearing a pair of dorsolateral outgrowth on its penial sac whereas *Neoperla* species B had four protrusions. The female of *Neoperla* A had a relatively larger vagina with more concentric folds of muscles than *Neoperla* species B. Larger micropyles and chorionic rugosity were more evident on the eggs of species A than B. A Principal Component Analysis of shape variation of the nymphs revealed that *Phanoperla* was more slender and longer than *Neoperla*. The males of *Neoperla* were relatively wider and shorter compared to females of both species. Females of *Phanoperla* have a relatively wider mesonota and metanota than those of the males.

Climate change in district Rajouri of Jammu Region, western Himalayas, India: local perceptions

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Over the past three decades, average surface air temperature in the Himalayas has increased 1.5°C, over double the global average rise of 0.6°C. We chose a small district, Rajouri, within the PirPanjal region in the western Himalayas in Jammu-Kashmir, India, as a model district to understand local perceptions of climatic change. Temperature and rainfall (gridded, 0.5° × 0.5° spatial resolution) for 1901 to 2002 from the Climate Research Unit, University of East Anglia, and ground data from Regional Agriculture Research Station were also examined (temperature during 2000 to 2011; rainfall for 2000 to 2014) to compare actual and perceived changes in climate. Simple linear regression using SPSS 16.0 showed significant changes in annual mean temperature from 1901 to 2002 ($p = 0.009$) in this region. No significant change in mean annual rainfall was observed from 1901 to 2002 or from 2000 to 2014. The perceptions of climate change among villagers from rural ($n = 519$) and urban ($n = 141$) areas were surveyed using a custom-made questionnaire adapted from Bohensky *et al.* (2012). The questionnaire included four sections: observation, risk perception, reactive action in response to the present, and proactive action in anticipation of future environmental change. The respondents stated they had observed increases in temperature, rainfall, wind speed and relative humidity (and, additionally, environmental pollution, traffic, crop-varieties and deforestation) over a 30-year period. Of the 660 persons interviewed, 87% viewed climate change as risk, 78% reported reactive actions, and 76% reported proactive actions. Our study concluded that the locals are conscious of climate change, but their involvement tends to be reactive, and proactive actions need more in-depth research.

Effects of geothermal operations on stream macro-invertebrate community structure

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Geothermal energy resolves the search for an environmentally favourable source of energy. It is a renewable and sustainable energy extracted from the heat of the Earth that can supply the increasing demand for electricity. With all the advantages being posted on the use of this alternative energy, it is important to ensure that its operations secure the integrity of the environment. Eight streams in the Leyte Geothermal Plant were selected and categorised as control or test sites relative to the geothermal plant and were surveyed for four years (2010, 2011, 2013 and 2014). To assess the conditions of these streams, several macro-invertebrate metrics (taxon richness, density, evenness, Simpson's diversity index, Ephemeroptera–Plecoptera–Trichoptera taxa richness and density, and Hilsenhoff Biotic Index) were calculated and analysed to determine patterns between sites and over time. Between sites, the diversity and sensitivity of benthic macro-invertebrates to organic pollution were similar (two-way repeated measures ANOVA, $P > 0.05$ in all cases), suggesting that all streams within the geothermal plant were in good condition. Over time, however, significant variation in taxon richness, density and evenness were observed (two-way repeated measures ANOVA, $P < 0.05$ in all cases), indicating a shift in macro-invertebrate composition. This change in community structure over time was not uncommon and occurred in both control and test sites. Our four-year study suggests that despite the geothermal operations, the integrity of the streams—based on their benthic macro-invertebrates—were maintained.

Integrated species identification of mayflies (Insecta, Ephemeroptera) from Layawan River of Mount Malindang, Philippines

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Accurate species identification is essential for conservation efforts. In many biodiversity studies only one method is employed due to limitations of time, resources and taxonomic expertise. Combining different methods of species identification provide a more robust assessment of biodiversity. This study sampled mayflies at 10 sites between 73 and 1,215 metres along the Layawan River of Mount Malindang. The obtained samples were identified through traditional taxonomic keys, morphometrics and DNA barcodes. We identified larval and adult specimens of the mayflies in nine and six species, respectively. The utility of geometric morphometrics for life-stage association of the mayflies was tested using homologous landmarks located on the face of late larvae and adults. Principal Component Analysis (PCA) of facial shapes showed distinct grouping between life stages within the Heptageniidae, Tricorythidae, Leptophlebiidae and Baetidae. Likewise, adults and larvae clustered closer within families and a defined space was evident between families. Two genera in the Heptageniidae showed a close grouping, however, suggesting there is more similarity in shape within than between different life stages. All mayfly specimens were from five different families (Tricorythidae, Teloganodidae, Leptophlebiidae, Baetidae and Heptageniidae), of which five species new to science (*Sparsorythus* sp. nov., *Dudgeodes* sp. nov., *Euthraulius* sp. nov., *Atopopus* sp. nov., and *Afronurus* sp. nov.) are herein described.

Competing land use practices in Xishuangbanna threaten regional biodiversity

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Xishuangbanna is situated in one of the world's 25 biodiversity hotspots, but its status as a biodiversity hotspot is under threat from various human-induced pressures. From 1976 to 2003, total forest area was reduced by 28%, whilst rubber alone expanded by 90%. Knowledge of how agricultural expansion and intensification affects arthropods is limited, but provides a useful metric and new understanding for managing ecosystem services important

to food security and biodiversity. Monocultures are rapidly replacing other traditional land use systems, with devastating and unpredictable effects on ecological processes, energy, water, and carbon balances. To mitigate the effects of potential invasions and loss of pollination services, biological control and natural community resilience, further knowledge of the impact of agricultural intensification and expansion is necessary. Arthropods play key roles in ecosystems and have been widely used to monitor environmental change. However, traditional methods of assessing arthropod biodiversity are time consuming, unreliable and require high expertise. Metabarcoding represents a powerful tool for biodiversity conservation and ecosystem management because it is more comprehensive, faster, reliable, and less dependent on taxonomic expertise. It is a fast biodiversity monitoring approach that integrates DNA taxonomy and high throughput DNA sequencing. Here we show the value of novel technologies in assaying the effect of various types of agricultural expansion and practice on arthropod biodiversity and discuss how we can use these technologies to measure changes in biodiversity and inform management.

Ex situ conservation of the rare and endemic species *Loropetalum subcordatum* in China

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Loropetalum subcordatum (Hamamelidaceae) is a rare and threatened endemic species to China. It is confined to the ravine woodlands of Guangdong, Guizhou and Hong Kong, China. Field surveys and molecular studies showed that the existing populations are small and low in genetic diversity. A small scale ex situ planting trial was conducted between 2006 and 2008 in Zhongshan City, Guangdong Province. Field growth monitoring showed that most of the trees in the planting site grew well in the ex situ site in 2011. In 2014, 72% of the trees produced flowers, but only 0.27–2.57% of trees set fruits. However, a few individuals died or were affected by pests including *Coptotermes formosanus*, *Drosicha corpulenta*, *Zeuzera leuconotum*, and *Holcocerus insularis*. Comparison of the photosynthetic characteristics of *L. subcordatum* in situ and ex situ showed that the trees of *L. subcordatum* were lower in both light compensation point and light saturation point than those of the canopy dominant tree *Sinosideroxylon wightianum* in their natural habitat. In the ex situ site, its maximum net photosynthetic efficiency and light saturation point were lower than those in situ, but the light compensation point was higher than those in situ. It indicated that the light adaptation of the individuals in the planting site decreased. Factors affecting the growth of *L. subcordatum* in planting site are discussed. A larger scale ex situ conservation and re-introduction of this threatened plant species in Guangdong is proposed.

Long-term monitoring of siamang in Bukit Barisan Selatan National Park: 17 years after ENSO-related wildfires

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The severe El Niño Southern Oscillation (ENSO) event in 1997 led to catastrophic fires across Indonesia. This study focused on the impact of wildfires associated with the 1997 ENSO event on a siamang *Symphalangus syndactylus* population in a Sumatran tropical forest. The aims were to assess the dynamics and persistence of siamangs and to compare the demographic characteristics of groups in burnt areas and areas untouched by the ENSO fires. Previous research has suggested that four years after the fires, siamang groups in previously burnt areas had a smaller group size, smaller home range, contained fewer non-adult individuals, and had a lower infant survival rate than groups in area not affected by fires. Annual censuses were conducted every year from 1997 to 2014 to monitor siamang populations in a 165 ha area, which was burnt in 1997, and in 635 ha unburnt control areas. Results indicate that by 2004 (seven years after the ENSO event), there were no significant differences between groups in burnt and unburnt areas in terms of group size and group structure. This indicates that in large and undisturbed forested landscapes, the impact of large fire events on siamang populations is relatively limited, and siamang populations are able to recover if burnt areas are allowed to regenerate.

Can environmental DNA save the Mekong giant catfish?

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To effectively conserve the Mekong giant catfish *Pangasianodon gigas* and other poorly known threatened species, it is essential to understand their natural history. While the giant catfish seems to have been abundant in the 1900s, it has since witnessed a dramatic population decline and is now listed as Critically Endangered. As few as one hundred individuals may still survive. Our research focused on environmental DNA (eDNA) technologies to detect fish in particular locations identified via the species' history and local knowledge. We sampled and filtered water at different depths and locations in and around deep pools in Laos, Thailand and Cambodia. The filters were analysed with a species-specific DNA amplification approach (eDNA barcoding), using DNA markers designed for this purpose, and a universal DNA amplification approach (eDNA metabarcoding), with a generic fish DNA marker. The eDNA barcoding approach was validated bioinformatically in vitro (using DNA extracted from tissue samples) and in situ (in reservoirs where the species is known to be present). Of the 12 sampled sites, *P. gigas* was detected once, in a location where it is believed to spawn in northern Laos and Thailand. The metabarcoding approach allowed identifying 21 families of fish over all sites and the Irrawaddy dolphin *Orcaella brevirostris* was detected in its range in Cambodia. We demonstrate that eDNA approaches represent a promising and powerful tool to monitor single key species or global biodiversity in complex aquatic ecosystems.

Human-wildlife conflict patterns and perception of local communities in the semi-arid landscape of Ranthambhore Tiger Reserve, Western India

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Human-wildlife conflict refers to the interaction and the resultant negative impact on wildlife and their habitats simultaneously on the livelihood of local communities. This study was carried out in and around Ranthambhore Tiger Reserve, Rajasthan during May 2013 to July 2013. Conflict data were collected and analysed for understanding patterns. Questionnaire surveys were conducted in 1,121 households covering 1,500 respondents from 50 villages to study the attitudes and perceptions of local communities. During last 10 years, 1,622 livestock were depredated in this region by wild carnivores. Leopards (75.37%) were mostly responsible for these casualties. One hundred and twenty-five cases of human injury and 10 cases of human mortalities were recorded in the last 10 years. Forty-seven wild animal deaths were also documented due to human involvement over the last seven years. Mean annual village conflict rates showed significant negative and positive correlations with distances of villages from the forest boundary ($\rho = -0.35$; $\alpha < 0.01$) and to the village livestock population ($\rho = 0.18$; $\alpha < 0.05$) respectively. Some respondents (22.86%) expressed negative attitudes towards wildlife, while the majority (73.93%) were positive. Most of the interviewees (98%) were dissatisfied with the current compensation system. Effective coordination among local communities and government agencies is crucial to efficiently mitigate human-wildlife conflict issues at Ranthambhore Tiger Reserve, Rajasthan.

Status assessment of some IUCN red-listed coral reef fishes in the Philippines

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The Philippines is within the coral triangle region, which is the global hotspot for coral reef ecosystems. Overfishing and various other anthropogenic threats have severely depleted the populations of coral reef fishes especially the large-bodied and slow-growing species that are currently red-listed by the IUCN. In this study, we surveyed coral reefs in more than 20 municipalities in the Philippines for four reef fish species on the IUCN Red List of Threatened Species, namely: bumphead parrotfish *Bulbometapon muricatum*, humpback grouper *Cromileptes*

altivelis, leopard coral grouper *Plectropomus leopardus* and humphead wrasse *Cheilinus undulatus*. In each municipality, data collection was conducted through fish visual census (FVC) by scuba diving in 8–10 10 x 50 m belt transects established on coral reefs with depths ranging from 8–12 m. Interviews with small-scale fishers were also conducted to determine fishers' knowledge on the occurrence of the studied species in their respective areas and to gauge the fishing pressure on these species. Results from FVC and local knowledge were integrated to determine the current status of these species. We also assessed the attributes of the sites and determined why some sites are better than others, in terms of biomass of these species. Unfortunately, since the surveys were conducted just last year, we are still analysing the data so we cannot yet provide the results of the study in this abstract. The results, though, will be very important in informing policy makers in prioritising management actions for effective conservation of these valuable but highly threatened coral reef fishes.

Can we cost-effectively manage increasing demand for natural rubber?

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Natural rubber plantations are key drivers of land-use change and biodiversity loss in Southeast Asia and Southwest China. Here, we review evidence of biodiversity loss associated with conversion of complex forest-agricultural mosaics and natural forests to rubber plantations. We then predict the area of future rubber expansion and ask whether carbon-based payments for ecosystem services (PES) are likely to cost-effectively stem the tide of forest conversion to rubber. Using industry estimates of future demand, we predict the likely area of new plantations under differing scenarios of yield, intensification of existing cultivation, and displacement of traditional rubber by oil palm. We estimate that between 4.3 and 8.5 million ha of new cultivation are required to meet projected rubber demand by 2024, threatening significant areas of Asian forest and biodiversity. We then investigate the carbon price required under PES to offset the cost of forest conversion to rubber and other expanding crops. We do so by: (i) calculating the profitability of timber harvest during the clearance phase, combined with the net present value of rubber and other crops; and (ii) using above-ground carbon stock data derived from tree sampling plots across Cambodia to calculate a carbon price equivalent to the opportunity costs. Our results indicate significant challenges for carbon-based PES to incentivise against conversion to rubber, especially in dry dipterocarp forests. We finish by highlighting key research directions to help mitigate the potential negative impacts of meeting future rubber demand.

Using plant functional traits and phylogenies to understand patterns of plant community assembly in a seasonal tropical forest in Lao PDR

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Combining phylogenetic and trait-based information can be a powerful approach for understanding community assembly processes across a range of spatial scales. We used this approach to investigate tree community composition in Phou Khao Khouay National Park, Laos, where several distinct forest types occur in close proximity. The aim of our study was to examine patterns of plant community assembly across the strong environmental gradients evident at our site. We hypothesised that differences in tree community composition were being driven by an underlying gradient in soil conditions. We surveyed 11 0.25-ha plots for all trees above 10 cm diameter at breast height (dbh) and sampled soils in each plot. For each species in the community, we measured 11 commonly studied plant functional traits covering both the leaf and wood economic spectrum traits, and we reconstructed a phylogenetic tree community using rbcL and matK sequences downloaded from Genbank. Finally, we compared the distribution of trait values and species among plots to examine trait and phylogenetic

community structures. Although there was strong evidence that an underlying soil gradient determined species composition at the site, our results did not support the hypothesis that the environmental filtering dominated the community assembly processes. For the measured plant functional traits, there was no consistent pattern of trait dispersion across the site, either when traits were considered individually or when combined in a multivariate analysis. However, there was a significant correlation between the degree of phylogenetic dispersion and the first principle component axis (PCA1) for the soil parameters. Moreover, the more phylogenetically clustered plots were on sandier soils with lower pH.

Iconic flagship species do not always serve umbrella functions

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Conservation planning outside reserves often relies on surrogate species, whose conservation may protect numerous others (umbrella species) or attract public support (flagship species). Government policy may emphasize the latter. Hence, spatial prioritization in fragmented, fast-developing landscapes may focus on conserving flagship species presence, with the implicit but untested assumption that they also serve umbrella functions. To evaluate whether Asian elephants *Elephas maximus* and tigers *Panthera tigris* do serve umbrella functions, we surveyed (via transects for animal sign and deployment of remote cameras from 2009 to 2013) a 302 km² multiple-use region connecting two tiger reserves in the Western Ghats biodiversity hotspot, India. We then: (1) built habitat-use regression models for elephants and tigers with camera data; (2) validated their predictive power with independent sign data; (3) examined correlations between flagship species habitat-use quintile and detection rates for 22 other mammals; and (4) regressed detection rates or presence of these other mammals on flagship species habitat-use. Detections of elephants, tigers and gaur *Bos gaurus* were positively correlated, and Nilgiri langurs *Trachypithecus johnii* were correlated with tiger habitat use. However, most other species—including threatened ones—exhibited ambiguous (e.g. lion-tailed macaque *Macaca silenus* and sloth bear *Melursus ursinus*) or even negative (e.g. sambar *Rusa unicolor*) correlations with the flagship species. This variation may reflect differential capacity to persist in secondary habitat, particularly when direct human-induced mortality also varies. We caution against assuming automatic umbrella benefits from iconic flagship species when prioritizing fast-developing landscapes and advocate a multi-species approach to land-use policy.

Towards dual sustainability: the need for conserving culture in nature conservation in tropical Asia

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Recent scholarly work has produced evidence that Protected Areas (PAs) are not only highly ecologically valued places but they are also rich sites for economic production and social relations which serve an indispensable part of local history and cultural identity among many indigenous communities. However, in practice, culture often comes second to the interest of saving fauna, flora and scenic environmental vistas, particularly in the tropical Asia region. Many conservationists contend that the losses incurred by local communities can be compensated. In this paper, using my ethnographic study of a displaced indigenous community known as Rana Tharus in far-western Nepal, their experiences provide us with two insights into the relationships between conservation, livelihood and cultural survival. Firstly, displaced Ranas suffered from landlessness, inadequate agricultural production and food insecurity. This led to further impoverishment. Moreover, displacement also led to serious household partitions. This severely damaged the patrilineal kinship relationships that had traditionally been a major source of informal security for Rana households, both economically and socially. Finally, this study seriously questions policy-maker perspectives whereby the social impacts of dislocation may be effectively mitigated by economic-focused resettlement programmes. They have ignored the close relationship between place, social networks, livelihoods and cultural practices. The study indicates that a more culturally inclusive conservation policy is necessary for achieving dual sustainability in nature conservation and livelihoods.

Traditional knowledge of wild and semi-wild edible plants used in Bali (Indonesia) to maintain biological and cultural diversity

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We report the first ethno-botanical study of wild and semi-wild food plants used by the inhabitants of the villages of Bali. Considering the urgent need to avoid the loss of this traditional knowledge, 50 informants from 13 "Bali Aga" villages across four districts were selected for our field investigation. Ethno-botanical data were collected through different interview methods (direct observation, semi-structured interviews, key informant interviews, individual discussions, focus-group discussions, and questionnaires). The 86 recorded species belonged to 41 families and 68 genera, including angiosperms (82) and pteridophytes (4) and were categorized as wild (33) and semi-wild (53). Of the 86, 63.64% are natives to Malesian, Indian, and Indochinese floras. Wild and semi-wild edible plants play an important role in providing the Balinese with various essential nutrients. Fourteen species (16.28%) are also used medicinally. With the growth of the tourist industry in recent years, the wild habitats of edible plants have been severely impacted. Traditional knowledge related to wild and semi-wild edible plants is also endangered. Therefore, the management of these resources and the preservation of biodiversity along with indigenous knowledge are of primary importance.

The evaluation of the educational programme "Knowing Elephant" in Xishuangbanna

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One-day visits are popular in informal educational institutions in China, such as botanical gardens. However, it is doubtful whether such programmes are effective, and to what degree. Well-designed, long-term educational programmes are needed to deeply influence the participants' behaviour, especially for conservation education. We developed and implemented an elephant conservation curriculum named "Knowing Elephant" for grade one middle-school students. The research found that students prefer varied and broad activities and the programme helped students to increase their knowledge of elephants and improve their willingness to be concerned about and conserve these animals. Ninety-three percent of students said that the programme was not an additional burden for them. However, it remains a challenge to integrate informal environmental education into the formal education system without sufficient funding and qualified teachers.

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Feeding activities and prey composition of the Sumatran cascade frogs: are they generalist predators?

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Sumatra is the sixth largest island in the world and has fascinating biodiversity, including herpetofauna. Unfortunately, the Sumatran herpetofauna is poorly understood, both in terms of its diversity and other biological aspects (e.g. feeding activity and prey composition). Although Ranidae are widespread, no studies have been undertaken on the feeding activity and prey composition of species in this family for decades. We therefore examined the stomach contents of Sumatran cascade frogs (*Hylarana crassiovis*, *Hylarana* sp., *Huia sumatrana* and *Odorrana hosii*, 291 specimens) that were collected from Aceh, West Sumatra, Jambi, and Bengkulu from 20 February to 15 May,

2014. We also calculated the composition and important prey components using Important Value Indices (Ix). Our results show that *H. crassiovis*, *Hylarana* sp. and *O. hosii* actively hunt from 2000–2100h and *Huia sumatrana* from 2100–2200 h. We also identified up to 24 types of prey. Orthoptera and Coleoptera were important prey items for these cascade frog species. This finding suggests that *Hylarana crassiovis*, *Hylarana* sp., *Huia sumatrana* and *O. hosii* select a wide range of food and may indicate that they are generalist predators.

Dimorphism and mating strategies in male *Sycoscapter* fig wasps (Hymenoptera: Pteromalidae)

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Having very few foundresses in each fig, male offspring inside a fig are very likely to be brothers and usually do not fight for mating access. However, male *Sycoscapter* fig wasps oppose this general pattern and do fight. The purpose of our study was to test the relationship between injury scores and male morphology as well as their exiting rates on *Ficus benguetensis*. Thirty ripe un-exited figs were haphazardly collected from Taiwan, and 42 males were identified and measured. We found that the mandible lengths of male *Sycoscapter* wasps had a positive and discontinuous relationship to head width, indicating the presence of two distinct morphs. As opposed to the prediction, no clear pattern could be found between body size and injury severity. Small males did not seem to suffer more severe injuries and there was no impunity advantage to being large. It was also notable that most of the injured body parts were antennae and tarsi, implying that these structures are more vulnerable or often the first appendages targeted during fighting. Surprisingly, about 49% of males exited from their natal figs, which also opposes the general assumption that wingless male fig wasps do not disperse. The high exit rate of male wasps may have been related to a reduction in aggression within the fig and perhaps moving to the neighbouring figs may offer a viable chance of mating access due to the clumped fruiting pattern of their host trees.

Cooperative conflict in fig–fig wasps system: the arms race between style and ovipositor length

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In fig–fig wasp mutualisms, because the offspring of pollinators and the viable seeds of the figs both use a common resource (female flowers), conflict (competition) will occur when the common resource is limited. This will promote an arms race between figs and pollinating wasps. According to arms race theory, while the female flower resource is limited, the pollinating wasps might evolve to have longer ovipositors to gain more chances to exploit the female flowers, while figs might develop longer styles to prevent the pollinating wasps from over-exploitation. However, the mechanisms that prevent the arms race between the style length of figs and ovipositor length of their pollinators from evolving limitlessly are still unclear. Furthermore, how the mutualism maintains stable under the competition of such an arms race is uncertain. Our experimental results show that the correlation between style and ovipositor length reflects an arms race between the figs and their pollinating wasps such that wasps that pollinate figs with long styles should possess longer ovipositors. In addition, environmental temperature influences the evolution of such an arms-race; and interference competition among pollinator wasps has been shown to reduce such an arms race between figs and their pollinators.

The contributions to the botanical journal *Sunyatsenia* from 1930 to 1948

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The botanical journal *Sunyatsenia* was founded by Professor Woonyoung Chun in 1930. The journal was named in

honour of Yatsen Sun, the founder of Sun Yat-sen University. *Sunyatsenia* was one of the earliest English taxonomic journals in China, and it was also a true international journal about plant taxonomy, systematics and floristic research. Many Chinese botanical research papers were published in the journal from 1930 to 1948, and it was praised as one of the most important botanical journals in East Asia. To help botanists understand this journal clearly, we checked all papers published in *Sunyatsenia*. The main results were: (1) A total of 41 researchers published 94 articles in *Sunyatsenia*, and many of them later became pioneers of Chinese botanical study; (2) 15 new genera, 386 new species and 45 new varieties were firstly described by a lot of famous botanists in *Sunyatsenia*, such as E.D. Merrill, W.Y. Chun, H.H. Hu, R.C. Ching, Y. Tsiang and H.T. Chang; (3) It also included some pioneering research papers, such as the famous "On Miquel's Kwangtung species as based on Krone's collection" and "On natural classification of the Family Polypodiaceae", "The vegetation of the Paracal Islands". Undoubtedly the botanical journal *Sunyatsenia* opened up and promoted early plant systematics, floristic geography, ecology, plant resources research in China. Furthermore, *Sunyatsenia* has been used to exchange taxonomic literatures with foreign research institutions, which promoted the academic communication of botanists.

Extremely low genetic diversity and extensive genetic admixture at the northern range margins of *Bombax ceiba*

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Understanding the evolutionary processes in species at their range margins is of great significance, because these marginal populations may harbour local adaptation and will initiate further expansion due to global warming. Most studies on patterns of genetic diversity at range margins have focused on temperate species, and species with a tropical distribution are less characterised. We examined genetic variation in two nuclear genes and one chloroplast intergenic spacer in 13 northern marginal populations and one geographically central population of *Bombax ceiba*, a tree species distributed mainly in the tropical regions. Our results revealed an extremely low level of genetic diversity in each population at the northern range margins and strong genetic differentiation between the South China and South Asia regions. Artificially cultivated populations and natural populations did not show significant difference in genetic variability. Genetic admixture was detected in 10 of 13 populations at the northern range margins in a nuclear gene. Founder effect, in which a small number of individuals of geographically central populations colonised the northern range margins after the ice age, may explain the extremely low genetic diversity. During this process, different source populations might mix and undergo further genetic drift and differentiation. This indicates that patterns of genetic diversity at the range margins of tropical species are very similar to those of temperate species and might be also severely influenced by founder effects after the Pleistocene glaciations. Populations of *B. ceiba* at range margins should be preserved because they are strongly differentiated from geographically central populations and may harbour local adaptation.

Forest islands in a rubber sea: developing methods to maintain and protect forests in a rubber matrix

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Xishuangbanna represents the northernmost part of the Southeast Asian tropics and is a biodiversity hotspot for China. The area is vulnerable to agricultural conversion, logging and mineral exploitation, causing high rates of forest fragmentation. To maintain forests requires two fundamentally different approaches: to understand how to maintain existing forests and protect vulnerable areas from future potential losses, in addition to strategic afforestation. We analysed the locations and vulnerability of remaining forest fragments and analysed patterns of deforestation over the last two decades using remote sensing approaches within ArcGIS. We also used social surveys to explore why these fragments had not previously been converted, and which remain due to ease of access relative to more ethnic and social reasons, and the implications for the future. We used modelling to ascertain which forest fragments are most vulnerable to future clearance. This allows us to understand the drivers of forest loss, and to work with managers and enforcement officers to protect vulnerable parts of the landscape

and maintain forest connectivity. Secondly we calculated the expected economic value of forest maintenance, and rubber profits in Xishuangbanna using various metrics. This allows us to calculate the potential land value and appropriate compensation to maintain forests. We discuss methods for developing and using this “rubber to rainforest” eco-compensation standard. Finally, we analyse the connectivity between remaining forest fragments and how it might be enhanced, and the relative costs and benefits of doing this in different parts of the landscape.

Understanding how the spatial distribution of forest fragments influences birds in a deforested landscape of southern tropical China

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Studies of fragmentation in heterogeneous environments must distinguish between effects of the fragmentation process itself (area of fragment, isolation, geometry of fragments in agricultural mosaic) and characteristics of where fragments are located (“location effects”: their elevation, aspect and soil conditions), because agriculture is a biased process with farmers selecting flat topography, easy access and fertile soils. Xishuangbanna Prefecture in Southwest China is highly threatened by the expansion of rubber plantations, and recent work has shown that in this undulating terrain with patchily-distributed limestone karsts, location effects may be particularly important in explaining the persistence of biodiversity in fragments, particularly for trees. But are these location effects also important for more mobile, short-lived organisms such as birds? We placed 47 point count stations within 24 forest patches, ranging in size from 0.09 ha to 13,872.87 ha. We conducted point counts at these stations three times, during the late dry season, the wet season, and the early dry season. One hundred and nine bird species and 3,185 individuals were observed. General linear mixed models indicate that location effects—specifically, topography, forest type (Fagaceae, mixed, limestone), and aspect—have more detectable effects than the fragmentation variables. However, the effect of fragment size can be seen for some classes of birds, such as the presence of open-landscape species (a negative relationship) or forest specialists (a positive one). This result suggests that managers should consider the location of remaining fragments in the landscape as well as fragmentation effects themselves to best protect biodiversity.

When two or more land use types compete, it is the biodiversity that suffers

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Xishuangbanna is situated in one of the world’s 25 biodiversity hotspots, but its status as a biodiversity hotspot is threatened by various human-induced pressures. From 1976 to 2003, total forest area decreased by 28%, whilst rubber alone expanded by 90%. Knowledge of how agricultural expansion and intensification affect arthropods is limited but provides a useful metric and new understanding for managing ecosystem services important to food security and biodiversity. Monocultures are rapidly replacing other traditional land use systems, with devastating and unpredictable effects on ecological processes, energy, water and carbon balances. To mitigate the effects of potential loss of pollination services, biological control and invasions, and natural community resilience, further knowledge of the impact of agricultural intensification and expansion is necessary. Arthropods play key roles in ecosystems and have been widely used to monitor environmental change. However, traditional methods of assessing arthropod biodiversity are time consuming, unreliable and require high expertise. Metabarcoding represents a powerful tool for biodiversity conservation and ecosystem management because it is more comprehensive, faster, reliable, and less dependent on taxonomic expertise. It is a fast biodiversity monitoring approach that integrates DNA taxonomy and high throughput DNA sequencing. Here we show the value of novel technologies in assaying the effect of various types of agricultural expansion and practice on arthropod biodiversity and discuss how these technologies can be used to measure changes in biodiversity and inform its management.

Echolocation calls of insectivorous bats in Gunung Mulu National Park, Sarawak, Malaysian Borneo

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Bats are keystone species that perform important ecosystem and economic services, have great potential as bioindicators of habitat quality and environmental change and are therefore important for monitoring. The karst landscape of Gunung Mulu National Park supports large populations and high diversity including 51 cave and forest roosting bat species. However, the dynamic ecosystem in Gunung Mulu National Park, with a combination of different types of vegetation surrounded by limestone karst, may hold more species that are yet to be discovered. The recent introduction of full spectrum, weatherproof acoustic recorders and associated spectrogram analysis software, facilitates the identification of species from their calls. This allows bats, and other organisms that produce calls for navigation and prey capture, to be a convenient group to survey. Herein, we describe the echolocation calls recorded from captured individuals of 24 species of insectivorous bats in Gunung Mulu National Park. The most frequently captured species were *Rhinolophus creaghi*, *R. borneensis*, *Hipposideros cervinus*, and *H. galeritus*, which are cave-dependent bats. Most species, in the family Rhinolophidae and Hipposideridae, differed in their range of call frequencies. However, some overlap in frequency of maximum energy was found for the calls of *H. cervinus* and *H. galeritus*, between 112 and 114 kHz. Female *R. creaghi* were found to produce calls at a higher frequency compared to males. Call variation among species provides resolution for species identification and highlights the importance of acoustic surveys to better document bat diversity.

Environmental factors influencing understorey cover and composition across the forest boundary in Mount Papandayan Nature Reserve, Indonesia

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Understorey vegetation is the least understood component of the forest despite its important role in ecosystem functions. The complex interactions between environmental conditions and understorey vegetation remain poorly-studied, especially in edge areas where the transition between forest and open land takes place. This study aimed to describe the floristic composition and identified the environmental factors influencing the composition and coverage of understorey vegetation across the forest boundary in Mount Papandayan Nature Reserve, Indonesia. In this research, 0.9 hectares of belt transects were laid out from the forest edge to the adjacent abandoned cropland. Abundance and coverage were measured in 180 plots, each 2 x 2 m. Environmental factors measured included soil physical and chemical parameters (temperature, humidity, pH, organic content, and bulk density) and canopy openness. Eighty species belonging to 39 families were recorded. The Importance Value Index (IVI) indicated a gradual change in species composition from the forest edge outwards. The forest area was dominated by *Elatostema integrifolium* and *Strobilanthes paniculata*, whereas *Ageratina riparia* and *Austroeupatorium inulaefolium* dominated the abandoned agriculture cropland. The Shannon-Wiener Diversity Index showed a decreasing diversity from the forest edge to the abandoned cropland. Based on the Principal Component Analysis (PCA) and the subsequent Stepwise Multiple Linear Regression Analysis, canopy openness seemed to be the most significant factor affecting understorey cover and species composition ($P < 0.05$, $R^2 = 0.657$). Spearman's Rank Correlation Analysis indicated that 31 species showed a certain preference towards higher light availability.

Exploring the interactions between *Ficus* (Moraceae) and non-pollinating fig wasps by comparative anatomy of fig wall structure

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Non-pollinating fig wasps can negatively affect the mutualism between fig trees and pollinating fig wasps. A

tough fig wall might serve as the first defence structure against external oviposition by non-pollinating fig wasps. My hypothesis is that the variety of non-pollinating fig wasps is related to the extent of fig wall specialisation. To investigate the tissue structure of fig walls of 16 *Ficus* species (six subgenera, containing five monoecious and 11 dioecious species), including variants in Taiwan, paraffin sections were made and histochemically stained. The results showed that fig walls of eight of the 16 sampled species underwent secondary morphogenesis, such as cell wall sclerification, which could deter non-pollinating fig wasps from externally ovipositing. Therefore, these species tend to have unsynchronised flowering and lower fig productivity. Generally, in the same subgenus fig trees share similar fig wall structure, but habitat type may affect the diversity of fig wall structure. For example, *F. pedunculosa* var. *mearnsii* has relatively simple fig wall and is distributed along the coral reef coast where few fig wasps can be found. In conclusion, fig wall structure could elucidate the co-evolutionary progress between fig trees and non-pollinating fig wasps.

Floristic diversity and patch dynamics in cyclone-disturbed and fragmented rainforests of Queensland

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Tropical cyclones are significant disturbance agents shaping the floristic composition, structure and functioning of forest ecosystems. The frequency and intensity of tropical cyclones drive forest ecosystems, such as those found in Mission Beach, North Queensland, towards a more or less continuous cycle of disturbance and reorganisation. Described in the literature as 'hyper-disturbed', these lowland rainforests are increasingly subject to the effects of habitat fragmentation. The two severe tropical cyclone events of Larry (2006) and Yasi (2011) raised questions over the likely response of rainforest fragments to severe and chronic disturbances. Will disturbance continue to drive resilience and diversity or will we see a collapse in ecosystem function and a shift towards a simpler forest structure with less floristic diversity and dominance of early successional species? Is it likely that new and novel ecosystems, dominated by alien plant species, will replace existing communities, and what potential is there for climate change to play a synergistic role in these scenarios? Few studies have examined the effects of hyper-disturbance at the community and species-levels in this context. This research aimed to examine evidence of any changes in floristic assemblages and structural characteristics across a disturbance gradient (i.e. continuous forest plots, forest edges and second-growth patches). It also aimed to test whether fragmentation and hyper-disturbance (post-Cyclones Yasi and Larry) are driving functional convergence in tree assemblages towards early-successional states. Preliminary findings suggest a far greater level of floristic diversity and community resilience than may have been previously expected.

Forest regeneration at the boundary of Mount Papandayan Nature Reserve, West Java, Indonesia

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Land use change from forests to agricultural fields occurred at the boundary of Mount Papandayan Nature Reserve in late 1994. However, agricultural activities eventually stopped and the fields have been abandoned since 2004. The existence of abandoned agricultural fields adjacent to forest provides a good setting for studying natural regeneration and role of forests as seed sources dispersing to the surrounding area. This study aimed to examine the natural regeneration in abandoned agricultural fields located adjacent to the forest edge in Pasir Leutik, Mount Papandayan Nature Reserve. The study compared the composition of forest and two types of abandoned agricultural field, i.e. undisturbed and disturbed by livestock grazing activity. Vegetation analysis was performed on three belt transects placed in parallel and extending from the forest to the undisturbed and disturbed abandoned fields. The results showed that the highest values of the species richness and the diversity index were found in the forest and the values declined across the abandoned agricultural fields. Of the 34 species found in the forest, 14 species were found in both types of abandoned agricultural fields; only five species were found in the disturbed field. Because there was no history of tree planting after field abandonment, the results indicate that the regeneration of the abandoned agricultural fields was facilitated by seed dispersal from the

adjacent forest. This study also suggests that the presence of grazing activity and the distance from the seed source (forest) affect the forest regeneration.

Phenology of *Ficus squamosa* (Moraceae) in a riparian habitat in Northern Thailand

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The reproductive phenology of plants is expected to be influenced by climatic factors and by the phylogenetic history of the species. Year-round flowering is widely reported in fig trees and is necessary for the survival of their short-living, specialised Agaonid pollinators. However, seasonality in fig production has been noted in almost all published phenological studies. A three year, phenological study of 174 mature trees of the dioecious fig *Ficus squamosa* Roxb. (Moraceae) was carried out in Chiang Mai, North Thailand. The presence of syconia (figs) and their phenophase was recorded biweekly in four study sites. This study aimed to describe the reproductive phenology of riparian fig species and correlate them with climatic variables. The quantity of syconia was correlated most significantly with temperature and rainfall. Fig production occurred year-round, with obvious high yield and low yield seasons. Figs were least abundant during the dry period or winter season (November–February) and most abundant from the summer season (April–June) through the rainy season (July–October). Fig production by the female trees was typically confined to the rainy season. Male trees reached a peak level of fig production in the months prior to the onset of female fig production and were more likely to produce figs continually. In summary, in this dioecious species, female and male trees initiated their maximal fig crops at different times. Being asynchronous both within-tree and among-trees, but with moderate concentrations during the hot and rainy months, could help to maintain the pollinator population under adverse conditions.

Species delimitation of *Ficus gasparriniana*–*F. erecta* complex of subsection Frutescentiae (Moraceae) with additional molecular data

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The *Ficus gasparriniana*–*F. erecta* complex includes about 22 traditional species of subsection Frutescentiae (*Ficus*, Moraceae). Many of these species are difficult to delimitate morphologically. To re-evaluate the species status of this complex, we checked: (1) phylogenetic trees derived from the nuclear ribosomal internal transcribed spacer (ITS) and external transcribed spacer (ETS), and the plastid psbA-trnH region; (2) phenogram of 18 fluorescently labelled microsatellite primers; and (3) 247 specimens and most of the related types. Phylogenetic trees revealed that the relationship among all members of the complex is close, of which *F. abelii* Miq., *F. erecta* Thunb., *F. formosana* Maxim., *F. pandurata* Hance, *F. gasparriniana* Miq., *F. pyriformis* Hook. et Arn. and *F. stenophylla* Hemsl. are always in a highly and stably supported clade. Morphological characters suggest that *F. fusuiensis* S.S. Chang, *F. undulata* S.S. Chang and *F. sinociliata* Z.K. Zhou & M.G. Gilbert should be considered as transitional forms of the species in this highly supported clade. Hence, we combined these 10 species as one: *F. erecta* Thunb. *sensu lato*. Next, with the support of simple sequence repeat (SSR) analyses, we established five new combinations in this species (i.e. *F. erecta* var. *stenophylla*, var. *pyriformis*, var. *formosana*, var. *pandurata* and var. *gasparriniana*) and confirmed 11 related new synonyms. Nonetheless, it is necessary to point out that according to molecular analyses, some samples named as '*F. gasparriniana*' based on morphology are close to two weakly-supported basal clades respectively, which probably means that gene flow exists between them.

Structure and composition of tree community along elevational gradient in Mount Gede Pangrango National Park

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Structure and composition of vegetation are affected by environmental factors. Along an elevation gradient,

variation in environmental factors has been widely reported to associate with changes in vegetation structure and composition. The aims of this study were to: (1) describe changes in the structure, composition, and diversity of trees along an elevational gradient; and (2) to determine vegetation zonation based on species composition of trees along the elevational gradient. This study was conducted in Mount Gede Pangrango National Park, in June–November 2014. Twenty-four quadrat plots were established in eight elevational sites from 1,400 to 2,800 m with an elevation interval of 200 m. At each elevation, vegetation analysis was conducted in three 20 x 20 m plots. Floristic zones were determined by clustering analysis with MVSP 3.1 based on Bray-Curtis dissimilarity index. In this study, 101 tree species were found. Families with high number of species were Myrtaceae (10 species), Fagaceae (nine species), Lauraceae (seven species), and Primulaceae (seven species). The mean tree height, species richness, and diversity decreased as elevation increased, whereas stem density and basal area increased with elevation. Three floristic zones were detected along the elevational gradient: zone 1 (1,400–1,800 m) dominated by Theaceae and Fagaceae, zone 2 (2,000–2,400 m) dominated by Theaceae and Myrtaceae, and zone 3 (2,600–2,800 m) dominated by Primulaceae and Ericaceae.

The adaptive phenology of *Ficus subpisocarpa* and *Ficus caulocarpa* in Taipei, Taiwan

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Occurring at the same humid subtropical northern Taiwan, *Ficus subpisocarpa* (a subtropical species) and *F. caulocarpa* (a tropical species) could share similar morphology and ecological niches. To compare the phenology of these two species, fig crops and leaf production of 64 *F. subpisocarpa* and 28 *F. caulocarpa* trees in Taipei were surveyed from April 2011 to December 2014. The developmental phases of figs were recorded as well as their height, diameter, volume, and weight. Both species showed continuous fig crops in summer, and elongated fig maturation in winter. Figs of *F. subpisocarpa* were produced all year round without obvious gaps, whereas *F. caulocarpa* did not produce figs during the winter. The two species are deciduous trees and had leaf flushing mostly during spring. Hypothetical correlations between phenological patterns and meteorological factors (rainfall, solar radiation, and temperature) were tested. *Ficus caulocarpa* production was more sensitive than *F. subpisocarpa* to meteorological factors when starting a new fig crop. Solar radiation and temperature showed correlations with the fig phenology of both species. This difference could be related to the evolutionary history of adaptation.

The Song Saa Marine Reserve—Cambodia's first government-recognised marine conservation area

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Established in 2007 as a Song Saa Private Island Initiative, the Song Saa Marine Reserve (a fisheries no-take zone) became Cambodia's first government recognised marine conservation area, protected by Royal Decree. Since 2013 the 5.5 ha Marine Reserve has been managed by the Song Saa Foundation in partnership with the Community Fishery of Prek Svay. With a greater abundance of invertebrates than surrounding sites, including the commercially caught giant clams *Tridacna gigas* and key commercial fish species, the Song Saa Marine Reserve sets an important precedent for Cambodia in terms of active private sector and NGO engagement in marine management. It also acts as a benchmark for the government's first proposed Marine Fisheries Management Area (MFMA) and future marine conservation efforts in the Koh Rong Archipelago to follow. With active involvement in the designation and management of the MFMA, the Song Saa Foundation maintains high expectations that the Song Saa Marine Reserve will continue to mature over the years to form an ecological legacy for local communities in the archipelago. The proposed ongoing ecological surveys and plans for reef rehabilitation (artificial reefs) will ensure the Marine Reserve continues to flourish as a conservation area. The longevity of the Marine Reserve is now ensured through the MFMA, under the category of a 'recreational zone', where access for non-invasive water sports is authorised and fishing is prohibited.

The status and distribution of primates in Phnom Kulen National Park, Cambodia: a report from surveys in 2013 and 2014

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Between December 2013 and December 2014, the Angkor Centre for Conservation of Biodiversity (ACCB) conducted surveys on the status and distribution of primates in Phnom Kulen National Park (PKNP), Cambodia. Surveys were conducted in collaboration with Cambodia's General Department of Administration for Nature Conservation and Protection (Ministry of Environment) and Integrated Solutions Asia Cooperation. The surveys confirmed the presence of primates through both direct observation and camera trapping. Interviews with local forest users were used to augment the observational data and to focus our survey efforts. Threats to habitats and species were identified during the survey, as were other wildlife species of interest. Four primate species were confirmed within PKNP by direct observation or camera trap, including Indochinese silvered langurs *Trachypithecus germaini*, pileated gibbons *Hylobates pileatus*, northern pig-tailed macaques *Macaca leonina*, and long-tailed macaques *Macaca fascicularis*. Observations included the first confirmed records of pileated gibbons on the eastern plateau of PKNP, where four groups were detected. Indochinese silvered langurs were observed in two new areas, but not detected in one previously occupied area on the eastern plateau. Though not confirmed, interviews suggested the continued presence of Bengal slow lorises *Nycticebus bengalensis* in PKNP. Habitat fragmentation and hunting appear to be the most prevalent threats to the remaining groups of endangered Indochinese silvered langurs and pileated gibbons in PKNP, which are now generally isolated in remaining native forest patches.

Can vocal characteristics predict leadership patterns in mixed-species flocks?

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What structures the organisation of mixed-species bird flocks (MSBF), so that some 'nuclear' species lead the flock and others follow them? Previous MSBF research has shown that species actively listen to each other and that leaders are gregarious. Such gregarious species tend to make contact calls and hence may be vocally conspicuous. We investigated whether vocal characteristics can predict leadership in MSBF, using a global dataset of MSBF studies and recordings from sound archives. We conducted fieldwork to see whether different recording equipment affected the amount of contact calls detected. Satisfied that this was not a confounding variable, we then investigated two questions using the sound archives. First, we asked whether leaders differ from species typically following or occurring as occasional species in flocks in the percent of recordings containing their calls, especially alarm calls. Leaders had a slight tendency to have a higher percentage of their calls rated as alarms compared to occasional species. Second, we investigated whether leading species calls differ from those of other species, hypothesizing that they might be: (1) delivered at a high and consistent rate (even when measuring at the per individual level); (2) simple acoustically and similar to each other, as contact calls tend to be; (3) more detectable, being low frequency and high bandwidth. Preliminary analysis showed that leaders differed from the other species classes only in that they were more vocal (a lower percentage of the recording was silent). We highlight the use of sound archives to ask questions about patterns of bird calls, discussing both the potential of such studies and their limitations.

Bird diversity in various forest types in KPH Probolinggo plantations, East Java, Indonesia

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Natural forests in Indonesia, especially in Java, have been converted to many other uses. This encourages conservation of habitats outside the natural forest area, which are expected to function as buffer areas. One form of

this conservation application is by creating forest plantations with various plant species to create different forest types. Forest plantations as natural forest buffer areas can become habitats for animals, especially birds. KPH Probolinggo has five forest types: teak, mahogany, damar, pine and kesambi. This study aimed to determine the diversity and composition of birds in the various forest types. The study was conducted in three BKPH (forest management units), i.e. Bermi, Sukapura, and Kabuaran. Data were collected from 17 June–17 July 2014 using 1-km transects. Species diversity was analysed using the Shannon-Wiener Diversity Index to determine the species diversity of birds, and variation of species composition was analysed using Sorensen's similarity and cluster analysis using Biodiversity Professional Software. The analyses showed that the diversity of bird species in each forest type was different: the pine forest 2,94; kesambi forest 2,93; mahogany forest 2,69; teak forest 2,42; and damar forest 2,75. The composition of bird species in each forest type varied: this was seen from the formation of four clusters and differences in bird communities between the various forest types. The highest diversity was in pine forest with complete age classes. Forest management is planned to complete the age classes in the other forest types.

Ivory and rhino horns consumption and consumers in Asia with a focus on China and Vietnam

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There is a high demand for wild animals and products made from them worldwide. Despite efforts undertaken by governments, non-governmental organisations and other parties to tackle unsustainable wildlife consumption, the consumption of wildlife products, including threatened species, in China and Vietnam has risen rapidly. Law enforcement action to apprehend poachers and illegal traders is the primary mechanism stemming these crimes. However, enforcement action alone may not be sufficient to eliminate this threat in the long term. The nature of the market is changing rapidly, with economic growth stimulating a status-driven consumption that goes beyond traditional uses. Consumption is now about complex social issues such as lifestyle, recreational choices, social, corporate status and aspirations. This research provides the first in-depth and comprehensive review of a wide range of communication materials that reached hundreds of millions of people across major markets in Southeast Asia, particularly Vietnam and China to raise awareness about rhinoceros horn consumption and its impact. It mapped the demand-reduction activities that are currently planned for major market countries for rhinoceros horn and ivory; identified values could be added to different approaches; identified distinct interventions that could be made more mutually supportive and complementary; and determined ways to avoid sending conflicting messages to the public. Some of the most successful techniques in changing consumer behaviour in other sectors have also been documented, including sustainable lifestyles, consumer choice and public health, and these can be adapted to reduce demand for elephant and rhinoceros products.

Patterns of Human–Elephant Conflict and mitigation techniques in Cambodia

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Human–Elephant Conflict (HEC) is a major threat to the Endangered Asian elephant *Elephas maximus* in Southeast Asia due to land use changes and human population increases. Settlement, agricultural expansion and development in and around elephant habitat have brought humans and elephant into increasing contact. Elephants raid crops and destroy property, negatively impacting people's livelihoods and possibly incurring injuries or death as a result of retribution. The Cambodian Elephant Conservation Group (CECG) was established in 2005 as a tripartite collaborative partnership between the Forestry Administration, Ministry of Environment and Fauna & Flora International in part to help mitigate HEC in Cambodia. The CECG team has helped community members across Cambodia to use different and changeable tools to harmlessly deter elephants away from their crops. Here, we present the results of the past three years of monitoring patterns of HEC across Cambodia, and report on the activities we have undertaken to help people mitigate HEC. As result of our efforts, affected local communities

are more tolerant, adaptive and coexist in the areas close to elephant habitats. There has been no reported retaliatory killing of an elephant in the areas in which we have been working.

The Karen Wildlife Conservation Initiative (KWCI): wildlife and forest conservation in Karen State, Burma

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Myanmar is currently in a period of political transition and as a result has lifted many restrictions on international travel to certain parts of the country. The region is a biodiversity hotspot and the Myanmar Government has had support from key international conservation organisations for many years, with more planning to engage with the government to support wildlife and forest conservation. However, the country still has ongoing regional disputes, with continued conflict or temporary ceasefires in place. Karen (Kayin) State is one such region, bordering Thailand's expansive forest complexes, where decades of military conflict have killed and displaced thousands of Karen, although a fragile ceasefire is currently in place. Much of this region is natural forest landscapes with high biodiversity, but there is limited access to data on the distribution or abundance of key conservation concern species due to a lack of capacity in the local governing administration (The Karen National Union) and their forestry department to undertake surveys, and a general and understandable suspicion and reluctance to then disseminate data or allow access to these regions to unknown organisations. While political negotiations on access continue, the wildlife and forest of the region are in peril from: increased hunting of prey species as displaced Karen return; targeted poaching of illegally traded species; illegal forestry; gold mining; and dam construction. KWCI was created as a partnership initiative to immediately increase the capacity of the Karen for surveying and protection of these unique habitats.

Diet and reproductive phenology of cave nectar bat *Eonycteris spelaea* in Cambodia and its conservation implications

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The diet and reproductive phenology of cave nectar bats *Eonycteris spelaea* are unknown in Cambodia. These were investigated at a colony inhabiting the Bat Khteas cave, Chhngauk Mountain (Kampot Province, southern Cambodia). Monthly sampling was undertaken from February to July 2014 that included: (1) Live-trapping to determine changes in reproductive status over time; (2) Collection of faecal samples from the cave to identify the plant species consumed by the bats by their pollen; and (3) Direct observations and interviews to determine human impacts on the colony. The diet of *E. spelaea* in southern Cambodia includes at least 18 plant species, a broader diet than that known for the species from southern Thailand. The most important dietary species were: mangrove apples *Sonneratia alba* (up to 44.8% per month), petai *Parkia speciosa* (up to 41.2%) and bananas *Musa truncata* (up to 35.6%). Reproductive data suggest that *E. spelaea* mainly gives birth in January and May–June in Kampot, in contrast to North Vietnam where birth peaks occur in March–April and August–September. *Eonycteris spelaea* is threatened by hunting for bushmeat and disturbance from guano collection in southern Cambodia, which increase during the Khmer new year period (April). Improved law enforcement and introduction of sustainable guano harvesting methods would reduce the impact of these activities on bat populations.

Current status of coral reef health around the Koh Rong Archipelago, Cambodia

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Abstract

Coral reef health is known to be in decline globally yet there is paucity of knowledge about the health of Cambodia's reefs. The Fisheries Administration aims to establish the country's first Marine Fisheries Management Area to protect their coral reef systems, and baseline data on current reef health were required. This study was carried out in the Koh Rong Archipelago between 2010 and 2014 with the objective of evaluating coral reef health to inform management approaches in the area. The survey methods were closely based on those of Reef Check, entailing the use of underwater transects to determine the density and diversity of corals, fish and invertebrates. An assessment of physical stressors on the reef was also undertaken. Fish diversity was found to be uniform throughout the survey area but there were localised pockets of higher density. Invertebrate diversity was also uniform, with little variation in density between sites. Hard coral communities were dominated by massive *Porites* spp. with zero incidences of coral disease noted. For the future, recommended monitoring tools in the Marine Fisheries Management Area include deploying permanent survey transects and thermal data loggers, and carrying out health survey assessments of the coastal mangrove forests and seagrass beds. It is also important to locate fish spawning sites, determine coral recruitment success, and quantify the impacts of sedimentation. Filling these knowledge gaps will provide further insights into the ecological stability of the archipelago's reef health, aiding future management strategies.

Keywords

Abundance, conservation, diversity, fish, invertebrates, marine protected area.

Introduction

Monitoring the health of coral reef ecosystems is not new, but a unified set of parameters to measure health has never been recognised. Over the past 40 years, a multitude of reef assessment methods have been designed by Risk (1972), Bryant *et al.* (1998), Downs *et al.* (2005) and Bruno *et al.* (2009), to name just a few. Collaborative discussions between marine biologists and resource stakeholders resulted in the

creation of the Global Coral Reef Monitoring Network (GCRMN) in 1995 under the International Coral Reef Initiative. The GCRMN promotes coral reef research and monitoring to inform national decision-makers about coral reef management, and strengthen understanding of global coral reef health. Coral reef assessments focus on descriptions of reef health and ecosystem responses at population and community

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levels, primarily with regard to coral cover, species abundance and population dynamics, covering an array of fish and invertebrate taxa (Risk *et al.*, 2001). Some approaches, such as those of the Caribbean Coastal Marine Productivity Programme (1997), take into account land–sea interactions, while others focus on patterns of change in community structure across a region by appraising taxonomic assemblages (Ginsberg *et al.*, 2000). The international NGO Reef Check aims to create a global database of wide ranging coral reef ecosystem health assessments (Hodgson, 2000), creating a snapshot-in-time of an array of key marine taxa in each location.

To date, few if any global reef monitoring programmes have successfully unearthed the large-scale mechanistic processes causing reef deterioration (Downs *et al.*, 2005). When assessing the health of a coral reef ecosystem, it is of paramount importance to monitor not only biological diversity and abundance, but also chronic and acute threats, and management actions. By focusing on these three areas—ecology, threats and management—it is possible to describe the current health status of a system and predict potential future health risks.

Management of coral reefs can range from protecting a single threatened coral colony to the creation of vast marine protected area (MPA) networks. In Cambodia, the first Marine Fisheries Management Area (MFMA)—a national term for a specific type of multiple-use MPA—is currently being established in the Koh Rong Archipelago by the Fisheries Administration (FiA) of the Royal Government of Cambodia (Fig. 1). The proposed MFMA has the potential to set a benchmark and framework for future marine conservation and protection measures along the country's coastline.

Globally, coral reef health is in decline. Previous studies have indicated that 58–70% of global reefs are threatened (Downs *et al.*, 2005) and this figure is likely to be even higher today. Therefore, it is of principal importance to gain an understanding, on a regional scale, of the health status of coral reef ecosystems and how best to protect them.

The FiA were aware of this in 2009 when they invited Coral Cay Conservation (CCC) to begin biophysical surveys of coral reefs in the Koh Rong Archipelago. The biodiversity and health of coral reef ecosystems along the Cambodian coastline are poorly understood, with a distinct paucity of information on marine habitats. Data from surveys conducted by CCC are now being used to describe the current

health of Cambodian coral reefs, and to aid the zoning of the proposed MFMA.

In 2010 and 2011, a preliminary investigation was carried out on a portion of the reefs that are the focus of this study. Van Bochove *et al.* (2011) noted that anthropogenic impacts were generally low, although evidence of fishery-related stressors was reported, including the depletion of key fish families. Sedimentation and siltation were recorded to be particularly severe in certain areas, perhaps due to seasonal rains. A mean hard coral cover of 25% was recorded in the sites surveyed, with rock and sandy substrates also common. In the study by van Bochove *et al.* (2011), commercially valuable fish families were identified as Serranidae, Scaridae, Lutjanidae, Haemulidae, Sphyraenidae and Carangidae. The population structure of these fish was also recorded in the area by Marine Conservation Cambodia (2011) and Savage *et al.* (2013). Thaug (2013) assessed spatial distribution of reef fish and invertebrates around Koh Rong, and Longhurst & Clay (2013) used CCC data to identify priority reef areas for conservation in the Koh Rong Archipelago.

Here we investigate the current health status of coral reefs around the Koh Rong Archipelago, and outline the threats that could directly affect the quality of ecosystem function and resource provision. We also suggest future management strategies in line with the proposed MFMA (Fig. 1) that could support ambitious national targets, such as allocating approximately 500 ha of coral reefs to an appropriate form of sustainable management by the end of 2015 (Fisheries Administration, 2011). The MFMA will reportedly entail 468 ha of coral reef, or 17% of the country's coral reefs, being brought under better protection (based on the estimated national total reef area of 2,806 ha: Mangroves for the Future, 2013).

Methods

Study area and field surveys

Surveys were undertaken by CCC staff and volunteers around three islands: Koh Rong, Koh Rong Sanloem and Koh Koun (Fig. 1). These are the largest islands of the Koh Rong Archipelago. For this paper, data will be presented from Koh Rong (10°42'N 103°14'E) and Koh Koun (10°37'N 103°19'E) only. Data from Koh Rong Sanloem are not included because research here is still ongoing.

The methods we used were closely based on those of Reef Check (Hodgson *et al.*, 2006). A few adjustments were made however, to overcome our low number of surveyors (e.g. we allowed a single diver to collect all invertebrate data on a transect, instead of the recommended two divers) and to make the surveys more applicable to local reefs (such as a slight change in indicator taxa, e.g. collector urchins *Tripneustes* spp. and flamingo tongues *Cyphoma gibbosum* were removed from the standard Reef Check list, while monocle bream *Scolopsis* spp. and jacks [Carangidae] were added, amongst others). Health parameters were closely based on the requisites for Reef Check, with key survey taxa including fish (Appendix 1) and invertebrates (Appendix 2), and substrate classification (Appendix 5).

Records were also taken of 'impacts', such as physical damage, general trash, fishing trash and disease prevalence (Appendix 3). Ancillary data were collected at every site to create a near-complete picture of potential stressors on the surveyed reefs.

Data were collected over four years from 2010–2014, with surveys carried out year-round. Sites were selected at c. 500 m intervals around the islands. The objective of this survey was to gain a comprehensive dataset pertaining to the entire archipelago's reef system. Data from van Bochove *et al.* (2011), collected between February 2010 and February 2011,

were incorporated. Seventy sites were surveyed and every site had four spatial replicates (Fig. 2), giving a grand total of 280 transects. Given the low taxonomic specificity in these methods (typically to family level), these spatial replicates were sufficient to capture the variation within one site, thus arguing that pseudoreplication was not a problem (Hodgson & Stepath, 1998). Every site was surveyed twice during the four-year survey period. Transects were deployed at depths of between 2 and 5 m depending on substrate topography. Every transect was orientated parallel to the shoreline, whilst keeping within the specified depth range. Data from all replicates were pooled for each site. Although permanent markers were not deployed, repeat surveys were carried out in the same area, guided by local landmarks and global positioning system coordinates.

Fish

Using a 20 x 5 x 5 m belt transect parallel to the shore, target species of fish were identified and counted (Appendix 1). Surveyors waited for 1 minute at the start of each survey and subsequently every 5 m along the transect to allow fish to return and disturbed sediment to settle. Fish were surveyed on the 'outward' direction of the survey dive, followed by the collection of invertebrate, impact and substrate data on the 'homeward' portion of the same transect.

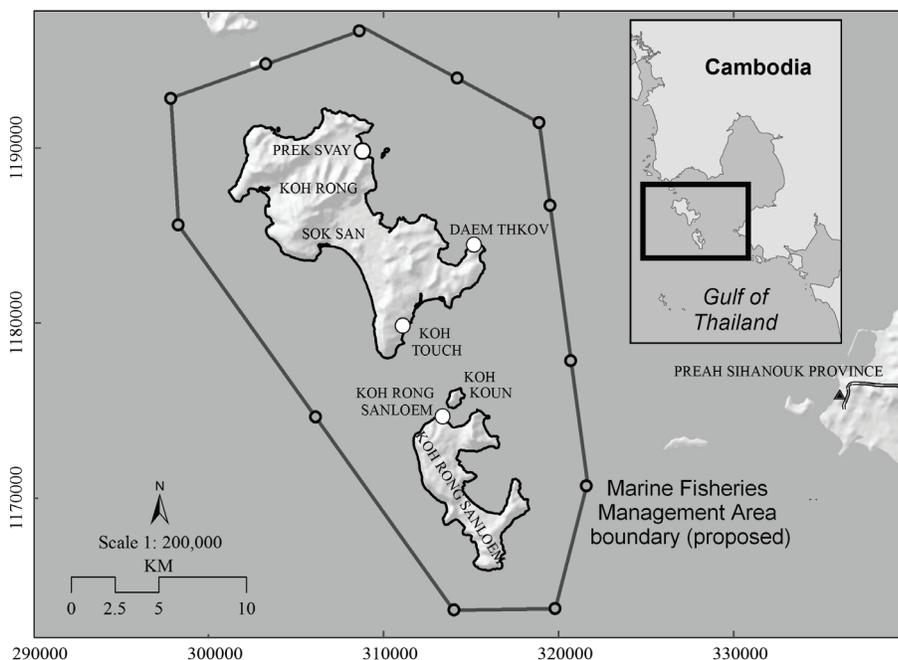


Fig. 1 Location and proposed border of the Marine Fisheries Management Area in the Koh Rong Archipelago.

Invertebrates and impacts

Using a 20 x 5 m belt transect in every survey site, the surveyors recorded the presence of each invertebrate target species shown in Appendix 2.

Incidence of impacts (Appendix 3) was also noted in the same belt transects. Where trash was found, we assigned a 'scale of impact' for general trash, and a separate ranking for fishing trash: *low* = 1 incidence of trash; *medium* = 2–4 incidences of trash; and *high* = 5 or more incidences.

Substrates

Using a 20-m point-intercept transect in every survey site, substrate was recorded at 50 cm intervals and classified according to Appendix 5. Substrates were grouped into categories for analysis: *Hard coral* encompassed all living hard corals; *Rock* encompassed bedrock, dead coral and recently killed coral (these were not differentiated in this study); *Unamalgamated substrate* encompassed sand, silt and rubble; *Other living substrate* encompassed any other living organisms, including soft corals, sponges, nutrient indicator algae, anemones, corallimorphs, zoanthids, *Halimeda* spp. and tunicates.

New coral recruits (colonies of <5 cm diameter, with the exception of *Pseudosiderastrea* spp. which naturally grow in small colonies) were also noted.

Ancillary data

At every survey site, distance from the nearest river mouth and river mouth width were estimated, as were distance from the nearest settlement and the settlement's size (human population size). Water temperatures were measured before each dive, both at the surface and at a depth of 3 m, using personal

dive computers. Identification of indicator taxa was confirmed using Allen *et al.* (2005) and Humann & Deloach (2010), when necessary.

Data analysis

The field data were entered into a Microsoft Excel database. Shannon's Index was used to quantify the diversity of fish and invertebrates on each transect. Maps were created using the software ArcGIS (ESRI Inc., Redlands, California, USA).

Results

Fish

The relative abundance of fish was highly variable (Fig. 3a). There were noticeable 'hotspots' to the north-west of Koh Rong, where mean density ranged from 161–200 individuals per 500 m³. Fish densities across the remainder of Koh Rong were noticeably lower, with only 0–120 individuals per 500 m³.

Fish diversity, quantified using Shannon's Index, was more uniform across the survey area (Fig. 3b). Whilst Koh Koun and northern Koh Rong displayed the highest index scores, of between 1.75 and 2.00, the remainder of the survey sites displayed a lower but uniform range. It was noticeable that the northwest coast of Koh Rong had both high fish density and high diversity.

Local commercially valuable species were in the families Siganidae, Lutjanidae, Nemipteridae, Lethrinidae, Carangidae, Sphyraenidae, Scaridae, and Haemulidae. The Haemulidae (sweetlips) were the most common, comprising 31% of all commercial fish in the archipelago, followed by Siganidae (rabbitfish) at 24% and Lutjanidae (snapper) at 20%. These

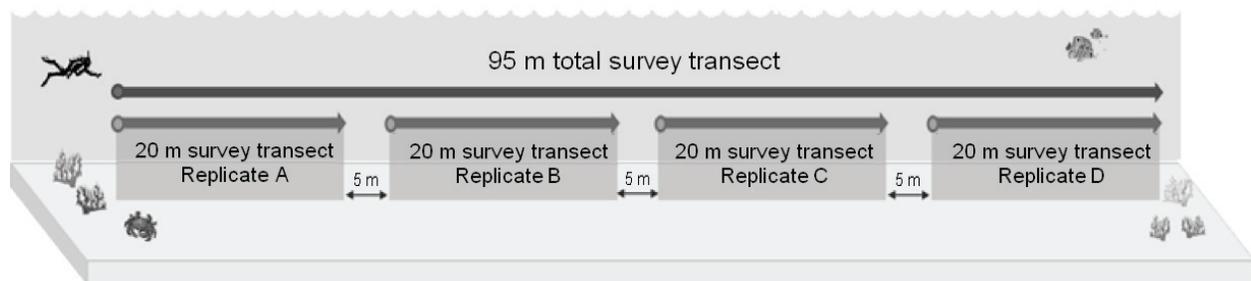


Fig. 2 Spatial distribution of transect replicates ($n = 4$) for each site (Mag Aoidh *et al.*, in prep.). The diagram is only indicative and not to scale.

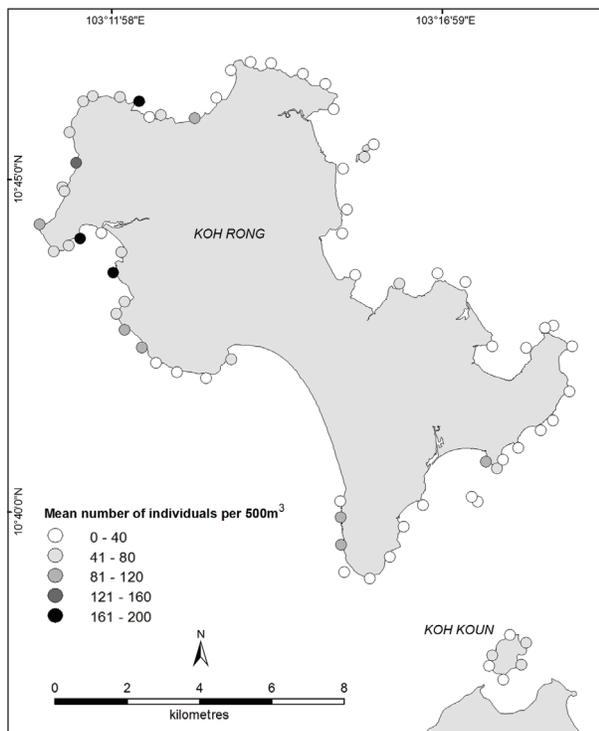


Fig. 3 (a) Fish density (individuals per 500 m³) in the Koh Rong Archipelago.

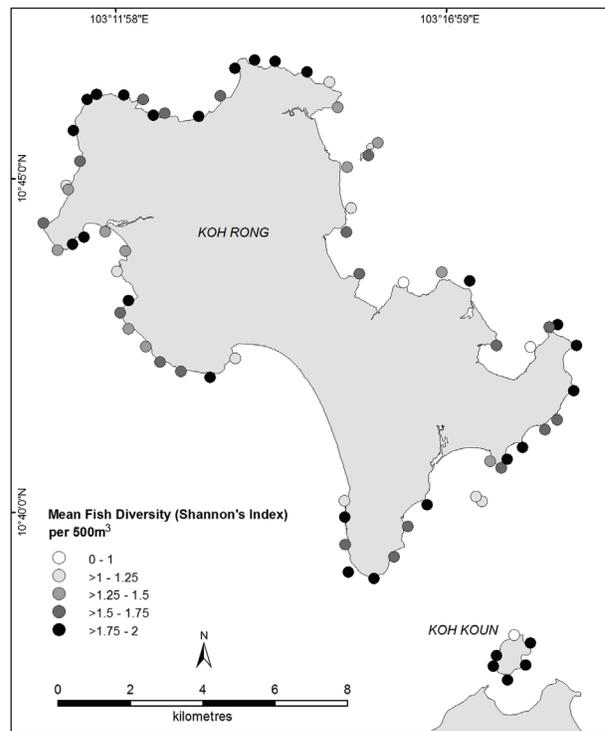


Fig. 3 (b) Fish diversity in the Koh Rong Archipelago, measured using Shannon's Index (per 500 m³).

three families were the most abundant commercially valuable fish ($n = 2,328$ fish).

Invertebrates

The overall density of invertebrates (pooling all species, but discarding the highly abundant *Diadema* spp. to avoid skewed outputs) was relatively similar across all sites with a typical range of 0–105 individuals per 100 m² (Fig. 4a). There was one notable exception to the south of Koh Rong, which had an elevated density of 141–175 individuals per 100 m².

Invertebrate diversity (Shannon's Index) was higher at the southern tip of Koh Rong (Fig. 4b). Invertebrate diversity was generally lower on the eastern sides of Koh Rong and Koh Koun, where there was a higher incidence of sandy/silty substrates and a lower incidence of rock/hard coral (Fig. 6).

Density of *Tridacna* spp. is a good indicator of water quality and reef health (Neo *et al.*, 2015) because clams are susceptible to increased water temperature, nutrient loading and poor water quality. During the four-year survey, 98 clams were noted, with a maximum of five clams per transect. *Diadema* spp. density was highly variable across the survey sites

($n = 6,965$ individuals): their density ranged from 0–7 individuals per m². Only four lobsters were seen during the survey, all on the same transect.

Impacts

With regard to physical impacts on the reef, there were two incidences of high impact fishing trash (such as ghost traps, fishing nets and rope), 10 incidences of medium impact fishing trash, and 24 incidences of low impact fishing trash (out of 70 sites). In addition, there were two incidences of high impact general trash (such as tin cans, clothing and construction materials), five incidences of medium impact general trash and 12 incidences of low impact general trash ($n = 70$ sites).

Even though we searched for signs of both black band and white band diseases, no incidences were noted during the four-year survey. Furthermore, there were only four incidents of anchor damage and one case of dynamite damage recorded during this study.

Substrates

Unamalgamated substrates were more common on the eastern side of Koh Rong and Koh Koun. Conversely, hard coral and rocky substrates were more common

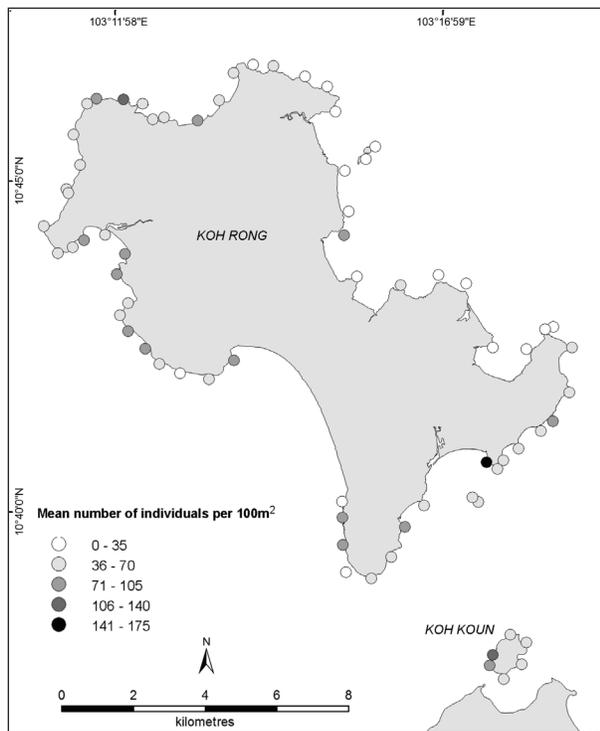


Fig. 4 (a) Invertebrate density (individuals per 100 m²) in the Koh Rong Archipelago, excluding *Diadema* spp.

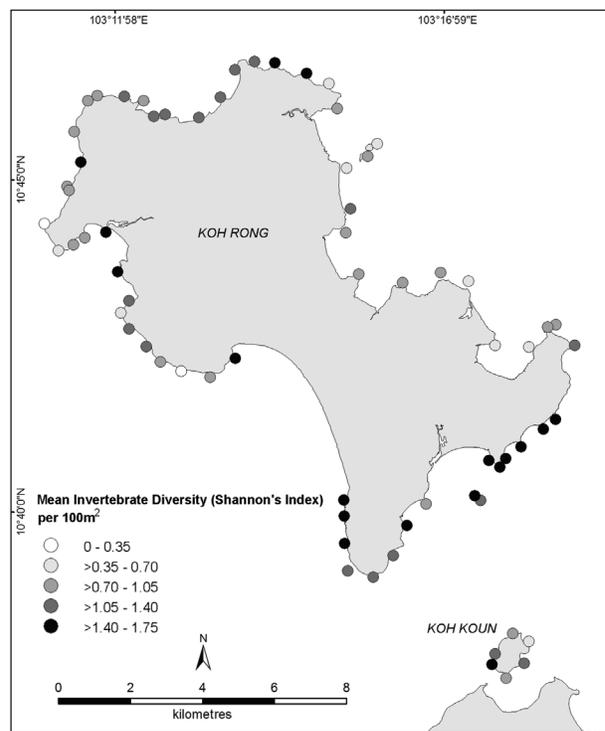


Fig. 4 (b) Invertebrate diversity in the Koh Rong Archipelago, measured using Shannon's Index (per 100 m²).

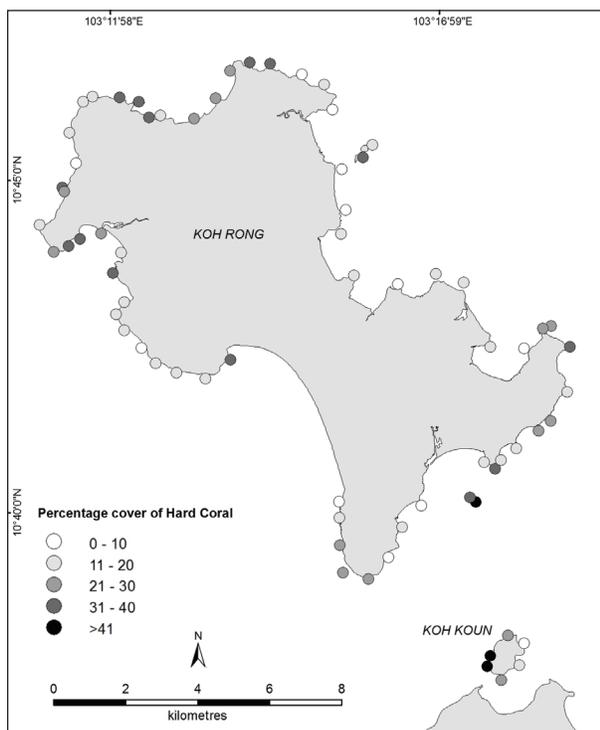


Fig. 5 Percentage cover of hard corals across the Koh Rong Archipelago.

on the northwestern reefs (Fig. 6). Koh Koun had low incidence of unamalgamated substrates and high hard coral cover (>41%), especially on the western reefs (Fig. 5).

Coral communities were dominated by massive and encrusting lifeforms (representing 47% and 25% of total hard corals respectively). Massive *Porites* spp. were the dominant coral species recorded (37% of total corals recorded). *Diploastrea heliophora* and *Favites* spp. were the next most common, at 10% and 9% respectively (Fig. 7).

Discussion

Fish

Fish abundance and diversity are good indicators of reef health (Hourigan *et al.*, 1988). A high abundance and high diversity of fish species indicates that the surrounding reef system is providing enough resources for their continued recruitment, growth and survival. Areas with fewer fish, such as the eastern side of Koh Rong, may be indicative of a poorer quality reef system or, on the other hand, it may also

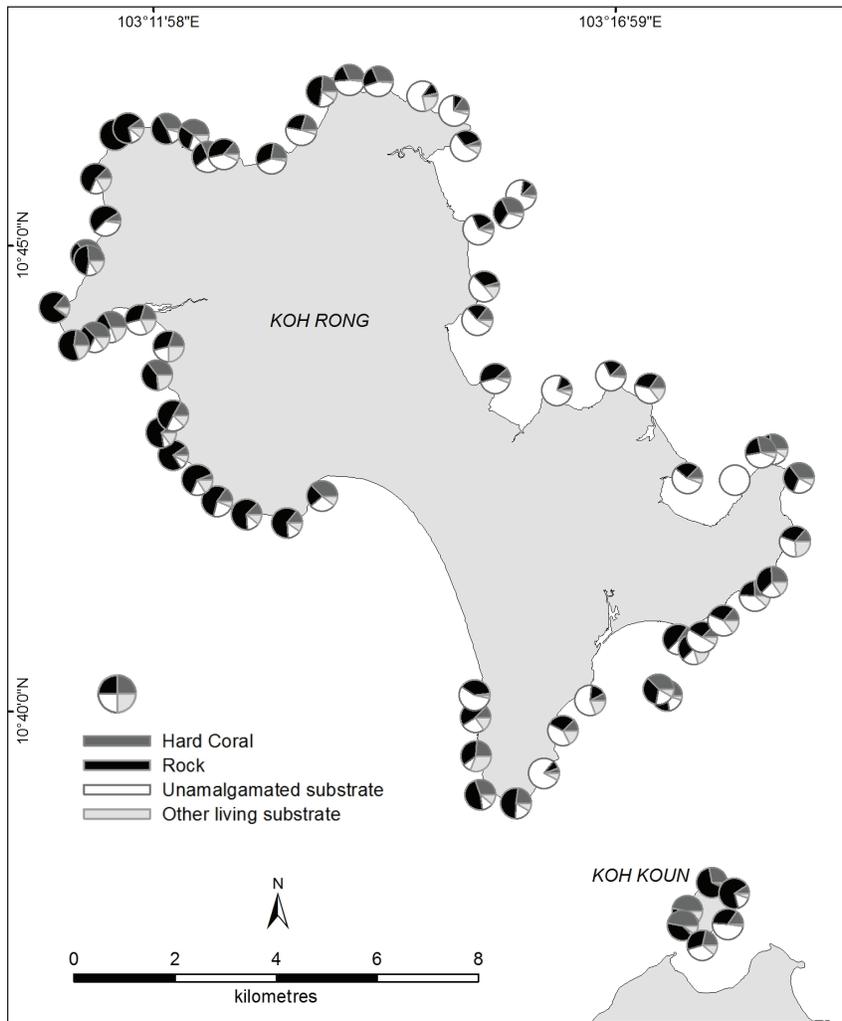


Fig. 6 Substrate composition across the Koh Rong Archipelago, showing rockier habitats to the west and more sandy/silty (unamalgamated) habitats to the east. Refer to the methods section for substrate classifications.

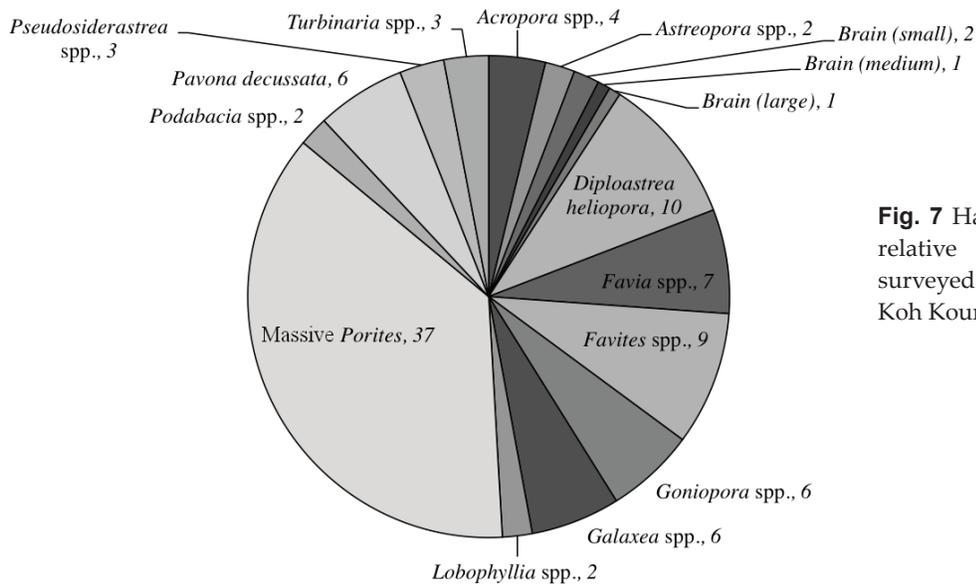


Fig. 7 Hard coral species and their relative abundance in the areas surveyed around Koh Rong and Koh Koun.

relate to natural variation in benthic topography and substrates. Many reef fish rely on corals and algae as a source of food: thus, if there is little coral growth there are likely to be fewer fish.

Sweetlips, rabbitfish and snappers are the most abundant commercially valuable fish species in the Koh Rong Archipelago. In comparison to published studies of reefs in other countries in Southeast Asia, the abundance of commercial fish in the Koh Rong Archipelago ranks first for parrotfish, second for groupers, and third for snappers and sweetlips (Table 1). This could be an important sign of good reef health, demonstrating that certain commercial species are not being overharvested. In Cambodia, local communities rely on reef fish as a source of income and food (Ouk *et al.*, 2011). The species caught reportedly have not changed over time, but in interviews with small-scale fishers, 95% perceived that their catches had declined (Leng, 2013), highlighting the urgency of avoiding further declines.

Invertebrates

Invertebrates are fundamental to the health of a coral reef. They enhance the resilience of reef ecosystems (Hoegh-Guldberg *et al.*, 2007), and through feeding on algae, act as ecosystem engineers, enabling the recruitment of crustose coralline algae and coral larvae (Todd, 1998).

Invertebrate density and diversity are relatively uniform across the archipelago, with the exception of one notably higher density site to the south of Koh Rong. Whilst invertebrate density appeared similar to sites surveyed in other parts of Southeast Asia (Table 2), we expected to see more holothuroids (sea cucumbers) on the Cambodian reefs. Sea cucumbers are integral to coral reef health because they recycle nutrients through a process of sediment bioturbation (Thorne *et al.*, 2013). Holothurians and *Tridacna gigas* are regarded as useful indicators of anthropogenic threats because trends in their abundance reflect

Table 1 The density of fish (individuals per 500 m³) in key commercial families in four Southeast Asian countries and the Koh Rong Archipelago in Cambodia. 'Rank' indicates the archipelago's position in relation to the other countries (on a scale of 1–5, where 1 is highest) for each taxon. Data for the other countries were collated from Chelliah *et al.* (2012).

Fish	Koh Rong Archipelago	Brunei	Philippines	Thailand	Malaysia	Rank
Lutjanidae (snappers)	7	1.45	2.14	20.63	11.13	3
Serranidae (groupers)	2	0.19	0.18	7.68	0.71	2
Chaetodontidae (butterflyfish)	3	1.73	12.57	6.2	4.47	4
Haemulidae (sweetlips)	0.13	0.26	0.06	0.02	0.25	3
Scaridae (parrotfish)	12	1.63	2.19	6.34	2.53	1

Table 2 The density of invertebrates (individuals per 100 m²) in four Southeast Asian countries and the Koh Rong Archipelago in Cambodia. 'Rank' indicates the archipelago's position in relation to the other countries (on a scale of 1–5, where 1 is highest) for each taxon. Data for the other countries were collated from Chelliah *et al.* (2012).

Invertebrates	Koh Rong Archipelago	Brunei	Philippines	Thailand	Malaysia	Rank
<i>Diadema</i> spp.	94	0.02	19.45	94.74	35.36	2
<i>Echinotrix</i> spp.	0.02	0	0.01	0	0	1
<i>Holothuria</i> spp.	0	0.5	0.02	1.61	1.56	5
<i>Acanthaster planci</i>	0.04	0.03	0.39	0.15	0.21	3
Nephropidae	0.03	0.04	0.03	0.2	0.01	3
<i>Tridacna gigas</i>	2	0.17	2.5	14.96	1.72	3

intensity of harvesting (Hopkins, 2009). *Tridacna* spp. have ecologically important roles as food providers, sources of shelter and reef builders (Neo *et al.*, 2015), and therefore a high density of these animals could be a good sign of a healthy reef. A deficit of *Tridacna* spp., on the other hand, could indicate a reef with reduced ecological functionality (Neo *et al.*, 2015).

The relatively high abundance of nudibranchs across the Koh Rong Archipelago and recent observations of nudibranch recruitment (Thorne, pers. obs.) indicate that water temperatures have remained comparatively stable since the May–October 2010 bleaching event (van Bochove *et al.*, 2011). Many nudibranch species have high thermal sensitivity (Clark, 1975), and overheating leads to lower fertility, bleaching of internal zooxanthellae, and death. Water temperature should be monitored using data loggers to ascertain the temporal trends. If another bleaching event occurs, these data would increase understanding of the reefs' resilience to, and potential impacts from, one of the causes of coral bleaching.

Diadema spp. (long-spined sea urchins) are important grazers of algae on coral reefs (Hoegh-Guldberg *et al.*, 2007). According to data collected during this study, sites across the Koh Rong Archipelago have up to seven individuals per m². This could be a sign that fishing pressure is high and herbivorous fish have been removed, resulting in an explosion of the urchin population. Or this could be a sign of high algal growth rates, thus supporting a high-density population of urchins. The urchins feed upon filamentous and macro algae, creating space for the recruitment of coral larvae (Carpenter, 1990). *Diadema* spp. show a preference for sheltered habitats among boulders where they can avoid predators and strong currents (Foster, 1987).

Substrates

There is a greater abundance of silt, sand and rubble on the eastern coastline of this archipelago, with a greater incidence of hard coral and rock substrates to the west. The abundance of invertebrates and fish mirrors this pattern. With fewer rocky outcrops for coral larvae to recruit upon, and fewer coralline structures for invertebrates to inhabit, there are consequently fewer fish. This is likely to be due to a paucity of their required food sources. Herbivorous fishes, like herbivorous invertebrates, require an abundance of specific algae in line with their digestive capabilities (Ogden & Lobel, 1978). Many of these algae grow on rocky substrates.

Hard corals are known to settle most efficiently on the upper surface of a rocky, coralline substrate, yet it is also known that the survival of coral recruits is greater on vertical surfaces (Birkeland, 1977). The benthic topography of Koh Koun and northwestern Koh Rong, where coral abundance is highest, is characterised by boulder-like and rocky outcrops. Based on the theory that sizeable horizontal and vertical surfaces promote the settlement of coral larvae, spatial variation in substrates may explain why hard coral cover and reef fish diversity varies from east to west in this archipelago (Thaung, 2013). Supporting this interpretation is evidence that coral larvae have very poor survival rates on unconsolidated substrates (Richmond, 1997), which are more predominant on the eastern side of the archipelago.

According to data from this study, coral composition leans heavily towards the massive growth forms, namely *Porites* spp., *Diploastrea heliophora*, *Favites* spp. and *Favia* spp. These are more stress-tolerant than branching corals (Edinger & Risk, 2000), such as *Acropora* spp. and *Tubastrea micrantha*, which are much scarcer in the archipelago. Reef systems that have an abundance of massive, stress-tolerant growth forms usually have few branching or foliose corals (Rodgers, 1990) as a result of sedimentation (Pastorak & Bilyard, 1985). An initial study of sedimentation around Koh Rong Sanloem (Yim, 2014) found that sediment rates appeared to vary greatly between sites. The greater incidence of massive corals in the Koh Rong Archipelago may be a result of high rates of sedimentation, preventing branching corals from thriving in these waters, or may be indicative of the boulder-like substratum, which tends to favour the recruitment of massive and encrusting corals (Birkeland, 1977). Yim (2014) also noted that turbidity might have more effect on reef health than sedimentation rates.

Coral and invertebrate diversity were found to be relatively uniform across the archipelago. In areas where corals are able to recruit successfully—i.e. where rocky and consolidated substrates are prevalent—their abundance and diversity appear stable. Fish diversity is also uniform throughout the archipelago. What is of concern, however, is the generally low density of fish found throughout the archipelago. There is enough reef habitat for the fish to reside in, enough invertebrates and algae for them to feed upon, and few natural large predators. As such, it could be assumed that the only remaining explanation for the low fish density is human exploitation through overfishing. Parrotfish are still abundant in the archi-

pelago, however, in comparison to other countries within Southeast Asia (Table 1), but are not necessarily targeted by local fishers. The shortage of commercially important holothurians and certain benthic invertebrates, such as lobsters, could be indicative of overharvesting (van Bochove *et al.*, 2011; Table 2). The noticeable lack of lobsters in our survey area, despite large areas of apparently suitable rocky habitat, could be due to ongoing overfishing in the area.

Implications of findings

The Koh Rong Archipelago is utilised by numerous stakeholders including businesses (mainly dive centres and coastal resorts) and local communities. Leaseholders now have agreements to develop large sections of the islands, which will undoubtedly have an impact on the adjacent reef systems over the coming years, such as increased terrestrial run-off (Skopal *et al.*, 2010). Tourism in the area is on the increase (Mulligan & Longhurst, 2014) and recreational diving is becoming ever more prevalent. This presents both threats and opportunities for the sustainable use of marine habitats, and the FiA hope to strengthen fisheries management by means of existing legislation in an attempt to protect the reefs within the archipelago. This will be enacted in the form of the Koh Rong Archipelago MFMA.

Data presented in this paper have already been used by the FiA to develop a zonation map to improve management of activities within the MFMA (Boon *et al.*, 2014). The proclamation of the MFMA will be a significant step forward in promoting sustainable resource use and may allow currently overexploited fauna to recuperate and their populations to expand.

Measuring the effectiveness of the MFMA is key for the FiA to determine progress towards their national target of 500 ha of coral reefs under an “appropriate form of sustainable management”. Changes in reef health and species composition can take time (Savage *et al.*, 2013) and, in the short-term, resource users are likely to be adversely affected (Scholz *et al.*, 2004; Mascia *et al.*, 2010; Pedju & Orams, 2013). A recent study in this area of finfish fishers and gleaners found they generally expected conservation zones in the MFMA to increase the number and size of fish, although 21.5% of interviewees thought conservation zones would negatively affect their access to fishing sites (On, 2014).

To monitor changes in reef health around the Koh Rong Archipelago after the MFMA is established, we

recommend that permanent transects are deployed at selected sites. The sites can be determined in accordance with the FiA zonation scheme and with the specific objectives and indicators for the MFMA. All data from the permanent transects, and the data from this study, should be openly available to the FiA for their use and dissemination. To facilitate this, training is being provided by the Song Saa Foundation to educate government officials in data analysis and Reef Check survey methods. The vision of the MFMA is not only to conserve threatened species in the area, such as the Critically Endangered hawksbill turtle *Eretmochelys imbricata*, but to conserve key habitats (mangroves, corals and seagrasses) and establish sustainable fishing practices to safeguard commercial fish species.

Baseline datasets are vital to determine management effectiveness and to inform future management actions (Savage *et al.*, 2013). Quantifying the changes in reef health and population composition may also help to show resource users and stakeholders that there are significant benefits to strengthening marine protection, despite potential short-term commercial losses for fishers (reduced access to key fishing grounds) and dive centres (reduced access to favourite dive sites). With Koh Koun displaying a high diversity of fish and invertebrates, and a high abundance of corals, this is certainly a hotspot for marine life in the archipelago. Likewise, the northwest of Koh Rong also demonstrated a high abundance and diversity of key taxa. These areas therefore merit particular attention to ensure their reefs are adequately protected.

Knowledge of specific ecological phenomena in the area is still relatively limited. For example, the locations of fish spawning sites, coral recruitment success, and the impacts of sedimentation rate and turbidity on coral reefs require further study. Filling these knowledge gaps would provide further insights into the ecological stability and resilience of the archipelago’s reefs, and would aid future management strategies. The composition of fish species and fish assemblage patterns vary greatly between near shore habitats (Sichum *et al.*, 2013), it is also important to collect biodiversity and health data in the habitats adjacent to the coral reefs, namely mangroves and seagrasses. Whilst some studies have already been completed for these habitats (e.g. Leng *et al.*, 2014; Mulligan & Longhurst, 2014), there is need for further research to ascertain the health of these important ecosystems.

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Appendix 1

Checklist of target fish in the Koh Rong Archipelago, showing mean family density (individuals per 500 m³) on transects in 70 sites, and whether the taxon was confirmed to be present during the study

Fish	Mean family density per 500 m ³	Observed during study
Lutjanidae (Snapper)	7	Yes
<i>Lutjanus decussatus</i>		Yes
<i>Lutjanus bohar</i>		Yes
<i>Lutjanus fulvus</i>		Yes
(All other Lutjanidae)		Yes
Nemipteridae (monocle bream)	4	Yes
<i>Scolopsis bilineatus</i>		Yes
<i>Scolopsis ciliatus</i>		Yes
Lethrinidae (emperors)	0.2	Yes
Carangidae (jack)	0.1	Yes
Sphyraenidae (barracudas)	1	No
<i>Sphyraena obtusata</i>		Yes
<i>Sphyraena barracuda</i>		Yes
(All other Sphyraenidae)		No
Serranidae (groupers)	2	Yes
<i>Cromileptes altivelis</i>		Yes
<i>Cephalopholis boenak</i>		Yes
<i>Cephalopholis argus</i>		Yes
<i>Cephalopholis formosa</i>		Yes
<i>Plectopomus areolatus</i>		Yes
<i>Epinephelus merra</i>		Yes
(All other Serranidae)		No
Sygnathidae (seahorses/pipefish)	0	No
Muraenidae (moray eels)	0	No
Chaetodontidae (butterflyfish)	3	Yes
<i>Chelmon rostratus</i>		Yes
<i>Heniochus acuminatus</i>		Yes
<i>Chaetodon octofaciatus</i>		Yes
Siganidae (rabbitfish)	8	Yes
<i>Siganus corallinus</i>		Yes
<i>Siganus virgatus</i>		Yes
<i>Siganus javus</i>		Yes

Fish	Mean family density per 500 m ³	Observed during study
<i>Siganus guttatus</i>		Yes
Pomacentridae (damselfish)	0.1	Yes
Amphiprioninae		Yes
Haemulidae (sweetlips)	0.4	Yes
Hemiscyliidae (bamboo sharks)	0	No
Dasytidae (blue-spotted ribbontail rays)	0	No
Holocentridae (soldierfish/squirrelfish)	3	Yes
Mullidae (goatfish)	1	Yes
Scaridae (parrotfish)	12	Yes

Appendix 2

Checklist of target invertebrate taxa documented in the Koh Rong Archipelago, showing mean invertebrate density (individuals per 100 m²) on transects in 70 sites, and whether the taxon was confirmed present during the study.

Invertebrates	Mean incidence per 100 m ²	Observed during study
Annelida (Segmented worms)		
<i>Spirobranchius</i> spp.	26	Yes
<i>Sabellastarte</i> spp.	8	Yes
Platyhelminthes (Flatworms)	0.3	Yes
Cephalopoda (Cephalopods)		
Teuthida (Order)	0	No
Octopoda (Order)	0	No
<i>Sepia</i> spp.	0	No
Gastropoda (Gastropods)		
<i>Calliosoma</i> spp.	0	No
<i>Drupella</i> spp.	6	Yes
Nudibranchia	3	Yes
Cypraeidae	2	Yes
(All other gastropods)	5	Yes
Bivalvia (Bivalves)		
<i>Tridacna</i> spp.	2	Yes
Crustacea (Crustaceans)		
<i>Stenopus hispidus</i>	0	No
Nephropidae	0.2	Yes

Invertebrates	Mean incidence per 100 m ²	Observed during study
Echinodermata (Echinoderms)		
<i>Acanthaster planci</i>	0.1	Yes
<i>Culcita novaguinea</i>	0.1	Yes
<i>Protoreaster nodosus</i>	0	No
<i>Diadema</i> spp.	94	Yes
<i>Echinotrix</i> spp.	0.3	Yes
Crinoidea	1	Yes
<i>Thelenota ananas</i>	0	No
<i>Stichopus chloronotus</i>	0	No
<i>Holothuria edulis</i>	0	No

Appendix 3

Incidences of impacts recorded on 20 x 5 m belt transects in 70 survey sites in the Koh Rong Archipelago..

Impacts	Total incidences during study	Observed during study
Anchor damage	4	Yes
Dynamite damage	1	Yes
General trash	111	Yes
Fishing trash (nets, rope, traps, etc.)	217	Yes
Coral disease (white band and black band)	0	No

Appendix 4

Checklist of target corals in the Koh Rong Archipelago, showing the mean frequency of corals on transects and whether the taxon was documented during the study.

Corals	Mean incidence per 20 m	Observed during study
<i>Acropora</i> spp.	0.4	Yes
<i>Astreopora</i> spp.	0.1	Yes
<i>Porites</i> spp.	2.6	Yes
<i>Goniopora/Alveopora</i> spp.	0.4	Yes
<i>Pavona decussata</i>	0.4	Yes
<i>Ctenactis echinata</i>	2.1	Yes

Corals	Mean incidence per 20 m	Observed during study
<i>Herpolitha limax</i>	0	No
<i>Polyphyllia talpina</i>	0	No
<i>Podabacia</i> spp.	0.1	Yes
<i>Galaxea</i> spp.	0.5	Yes
<i>Pectinia</i> spp.	0	No
<i>Lobophyllia</i> spp.	0.1	Yes
<i>Diploastrea heliopora</i>	0.7	Yes
<i>Echinopora</i> spp.	0.04	Yes
<i>Euphyllia</i> spp.	0	No
<i>Plerogyra</i> spp.	0	No
<i>Tubastrea micrantha</i>	0	No
<i>Turbinaria</i> spp.	0.2	Yes
<i>Pseudosiderastrea</i> spp.	0.2	Yes
Brain coral (small, medium, large)	0.4	Yes (all three)
<i>Tubipora</i> spp.	0	No
<i>Millepora</i> spp.	0	No
<i>Heliopora</i> sp.	0	No
<i>Favia</i> spp.	0.5	Yes
<i>Favites</i> spp.	0.7	Yes

Appendix 5

Checklist of target substrates in the Koh Rong Archipelago, showing whether the substrate was observed during the survey.

Substrates	Observed during study	Substrates	Observed during study
Rock (geo-bedrock and dead coral)	Yes	Sponge	Yes
Rubble	Yes	Recently Killed Coral (RKC)	Yes
Sand	Yes	Anemone	Yes
Silt	Yes	Zoanthids	Yes
Nutrient Indicator Algae (NIA)	Yes	Corallimorphs	Yes
Hard coral (detailed above)	Yes	<i>Halimeda</i> spp.	No
Soft coral	Yes	Tunicates	Yes

Instructions for Authors

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